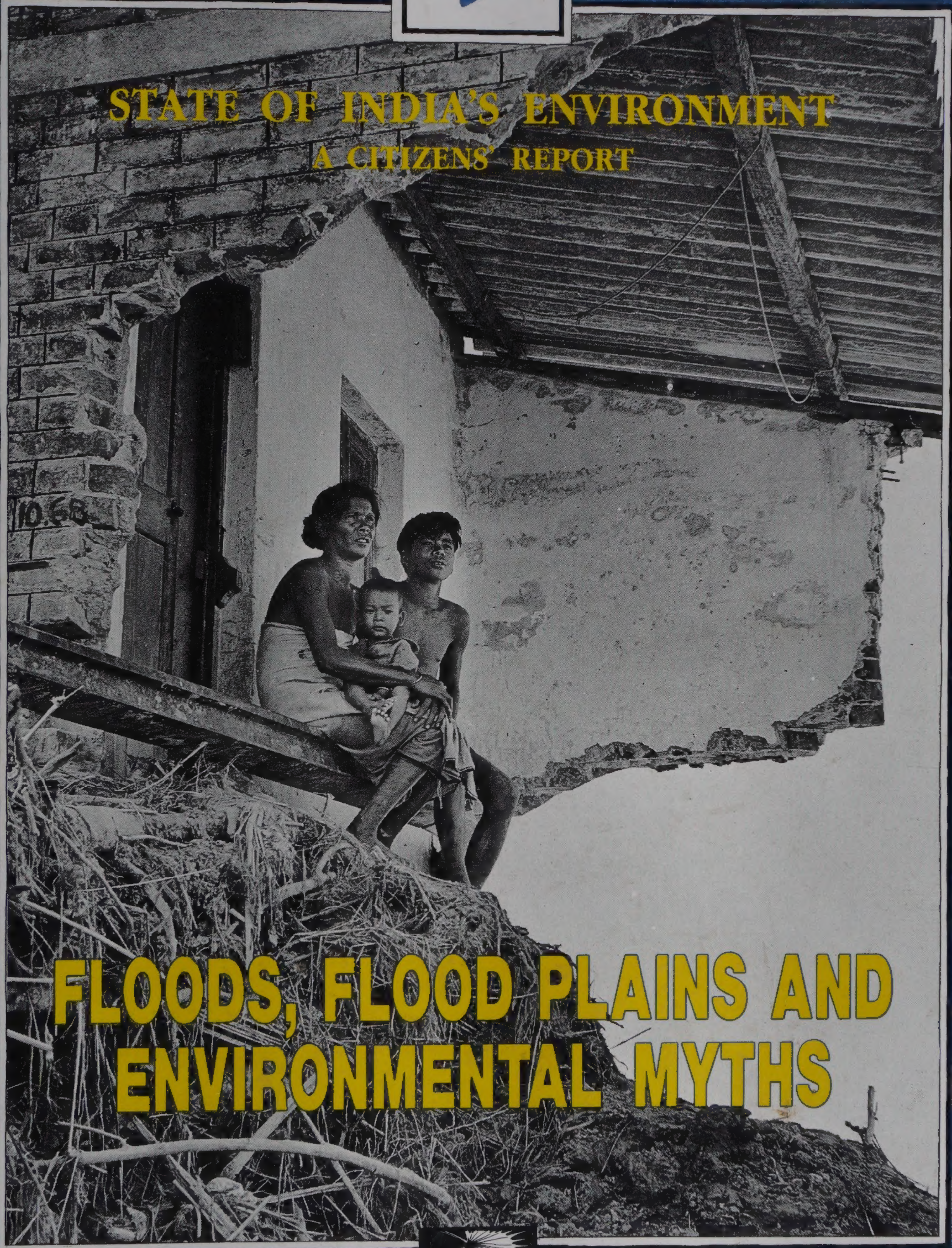
3



STATE OF INDIA'S ENVIRONMENT
A CITIZENS' REPORT

FLOODS, FLOOD PLAINS AND ENVIRONMENTAL MYTHS

CENTRE FOR SCIENCE AND ENVIRONMENT

3

STATE OF INDIA'S ENVIRONMENT

A CITIZENS' REPORT

FLOODS, FLOOD PLAINS AND ENVIRONMENTAL MYTHS

CENTRE FOR SCIENCE AND ENVIRONMENT

LEAVES OF IMPORTANT SURVIVAL TREES IN INDIA – MAHUA, KHEJDI, ALDER, PALMYRA AND OAK.

TO THOSE
WHO HAVE LEARNT
TO LIVE
WITH FLOODS

This report supplements the information provided in the State of India's Environment — 1982 and State of India's Environment — 1985 and is not a substitute for them.

Cover designed by
Rajiv Manikoth

Cover photograph by
N. Thiagarajan

Designed and printed by
Vision Wordtronic Pvt. Ltd.
111 Eros Apartments
56 Nehru Place
New Delhi - 110 019
Phones: 6445895, 6448418

Published by
Centre for Science and Environment
807 Vishal Bhawan
95 Nehru Place
New Delhi - 110 019
Phones: 6433394, 6438109

Contents

Introduction v

CHAPTER 1 **Pandemonium in the Plains** 1
- Flood Incidence
- History of Flood Control
- The Environmental Connection

CHAPTER 2 **Havoc in the Himalaya** 23
- Floods in Garhwal
- Floods in Teesta

CHAPTER 3 **Deforestation: The Bare Facts** 41
- The Himalayan Environment
- Impact of Human Intervention
- Conclusion

CHAPTER 4 **Annual Mayhem in Assam** 71
- Extent of Floods
- Causes of Floods
- Ways Ahead

CHAPTER 5 **Nightmare in North Bihar** 95
- Ecological Setting
- Historical Background
- Flood Control after Independence
- Flood Protection: An Assessment
- Alternatives

CHAPTER 6 **Crisis in the Diara** 127
- Survival in the Diara
- Diara Violence
- Ecological Change

CHAPTER 7 **A Truce with Nature** 147

Appendices 154

References 160

Glossary 166

STATE OF INDIA'S ENVIRONMENT

Floods

Series Editors :

ANIL AGARWAL and **SUNITA NARAIN**

This report has been edited by **Anil Agarwal** and **Ajit Chak**.

It has been written by **Anil Agarwal, Neeraj Labh** and **V.A. Nambi** with the help of additional contributions from **Mukul Sharma**, **Ajit Chak** and **Sangeeta Synghal**.

This report would not have been possible without the support of **Amarjeet Sinha,** Chaibasa; **Richard Holloway,** Dacca; **Chandi Prasad Bhatt,** Gopeshwar; **Dulal C. Goswami,** Guwahati; **D.N. Borthakur,** Jorhat; **Arun Kumar,** Katihar; **C. Mumtamayee,** New Delhi; **B.B. Karajage, Mammen Mathew, Hemant, Kamla Prasad, P.P. Mittal, Malti Sunila Sinha, P.K. Chaudhary, Rajiv Jha, K. Balchand, Urmilesh, Uttam Sengupta, Sarju Rai, Raghupati, Basawan Sinha, J. Bahadur, L.S. Prasad, M.K. Sahai** and **J. Prasad,** Patna; and **V.P. Saran,** Ranchi.

Work on the report was coordinated by **Anil Agarwal** and **Ajit Chak**.

Illustrations and maps were made **Neeta Gangopadhya, Piremender S.Sirohi, Susmita Saha** and **Gopa Kumar**.

Several organisations and individuals provided photographs for use in the report.

The editors are extremely grateful to the late **Rajiv Gandhi** for his interest in the State of India's Environment reports.

Introduction

It was in 1985 that the second citizens' report on the State of India's Environment was published. Over five years have since gone by. It is not that we have not tried hard to publish the third report since then but producing it has proved to be a veritable minefield.

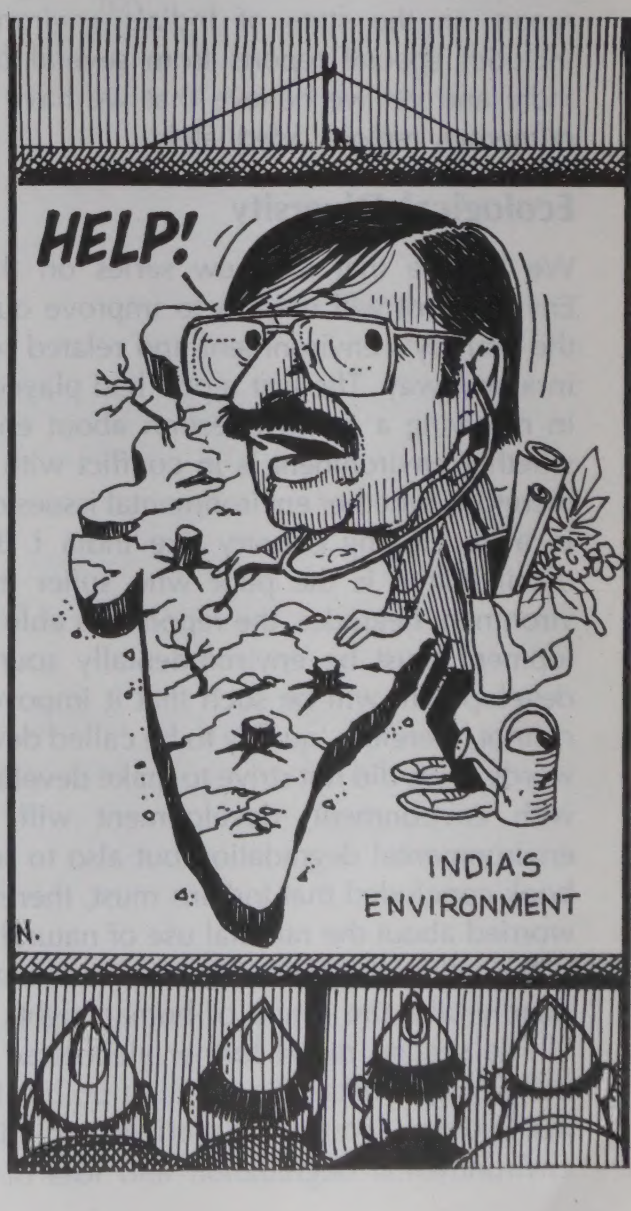
Several things have changed since the mid-1980s. The Indian environmental movement took off in the early 1980s. But at that time there was limited interest in environment both within the government and amongst voluntary agencies. Producing a report on the state of India's environment was then a relatively easy task. Information was limited and information flows were small and slow. The first report, which we published in 1982, was produced within a period of less than a year from its conceptualisation to final printing. But we could never repeat that achievement and the second took about three years to produce. The main reason why the second report took longer, even in the mid-1980s, was the already rapidly growing information in the field. And where the information was not available, it required detailed data gathering and investigative journalism to collect. So the second report took much longer to produce than the first one.

The third has taken an even longer time because of this reason, among others, of course. A lot has been happening in the field of environment in India, particularly since the mid-1980s, in the form of numerous NGO campaigns and projects and government programmes. Therefore, the task of preparing the environment reports has also become far more difficult. We now have to document events and processes as they happen and unfold. We now find that completed chapters go out of date even before we reach half the book. The result is an unending chase to document changing events in an ambitious attempt to produce a comprehensive report.

Of course, there have been other problems on the way which have repeatedly diverted our attention from the production of the state of the environment reports. As attention and interest in environmental issues began to grow, people began to tell us, "its easy to state problems but why don't you suggest solutions ?" These would often be bureaucrats and technocrats who were not convinced by the growing environmental concern.

We knew that the solutions are all around us, in the work of the people of this country. So we spent a lot of time interacting with people working in the field and learning from their micro-experience to translate them into macro-policies. This kind of work, which moved away from journalism into policy research, meant that we could not devote the full time attention that we could do earlier to the production of the 1982 and 1985 reports. As a result, the production of the third report suffered.

But our readers have not let us forget that a third report is needed. There is hardly a day or week that goes by without someone not writing to us or asking us when is the third report coming out. Orders also keep coming in. The earlier reports were read extremely widely within both governmental and voluntary agency circles, by students and professors, and in India and outside. Numerous institutions placed orders, for instance, for all district rural development agencies, environmental institutions, forest agencies and the like.



The high point of the reports was an invitation by the Prime Minister, Shri Rajiv Gandhi, to the editors to address a special meeting of the Union Council of Ministers on the findings of the report. The Prime Minister later requested that the same presentation also be made to all the 27 Parliamentary Consultative Committees attached to the various Union ministries. This was unprecedented governmental attention to a book in India.

The New Reports

Having gone through a difficult experience over the last five years to produce the third report, chasing events which continue to move with considerable rapidity, we have now decided to publish the third report not as a comprehensive report but as a series of reports on specific issues. We will publish each report as soon as we complete our manuscript. This will definitely dilute the impact that the earlier reports had. The new reports will not be able to present an overview of India's environmental concerns within one volume as earlier reports had done. But there will be two major advantages now. One, we can now publish our reports much faster as and when one issue has been researched adequately. Two, this strategy provides us with an opportunity to deal with an issue in depth. In a comprehensive report, it was not possible to devote more than dozen or two dozen pages to one issue. This was adequate when we were mainly describing problems. But that is no longer adequate when we want to move towards solutions. This is all the more true for India, a country which has an extraordinary ecological diversity, where what is true for one region is not true for another.

The first such report that we present to you in the new format is on the problem of floods in India. The ecological and social settings within which floods take place in India are so diverse that it would be difficult to deal with this issue in any depth in a few pages. The report on floods alone has finally turned out to be almost as big as the entire 1982 report on the state of India's environment. This report includes special reports from several different regions of India and yet we believe that we have not yet dealt with numerous regions adequately.

Ecological Diversity

We believe that the new series on the State of India's Environment will help us to improve our understanding of the country's environment and related sociopolitical issues in a new way. The first report had played an important role in resolving a major question about environment, that is, whether environment is in conflict with development and, therefore, whether environmental issues ought to get priority in a developing country like India ? By documenting in detail that it is the poor who suffer most when the environment degrades, the report was able to show that development must be environmentally sound. Otherwise that development will be such that it impoverishes people and cannot, therefore, qualify to be called development. In other words, if we did not strive to make development harmonious with environment, development will lead not only to environmental degradation but also to social injustice. The book concluded that Indians must, therefore, be even more worried about the rational use of natural resources than the rich nations. Otherwise, environmental concerns will rapidly take the shape of human rights concerns.

The second report further elaborated these concerns by describing in detail the plight of politically marginal groups like women, nomads, fisherfolk and tribals as a result of environmental degradation and loss of control over their natural resource base. The report also elaborated how the poor depend on a biomass-based subsistence economy for their survival.

These ideas have since gained considerable currency and are now widely accepted both by environmentalists and development planners, researchers and analysts. Time has also thrown up numerous movements in India where human rights and environmental concerns have been deeply intertwined.

We hope that our future reports, which will now be available on specific issues but in greater depth, will help us to become acutely aware of the diversity of ecological conditions that we are confronted with in India and how this affects the socioeconomic dynamics and survival of the poor in a myriad different ways. So that as we try to move towards an environmentally sound path of development, we can fine tune our policies to deal with the extraordinary socioecological diversity that exists in our country.

In fact, this report points out to some of the environmental myths that can crop up when we continue to deal with major problems, which occur in different ecological settings, with the same generalities. Good environmental management demands that we learn to deal with ecological specificities, especially in India where our natural resources are under considerable pressure.

For instance, the report points out that floods in the plains below the vast Himalayan ranges may not be greatly exacerbated by deforestation. Floods are, in fact, and will remain, an inherent feature of these plains whether the Himalayan mountains are well clad with a green cover or whether they are deforested and barren. The Himalayan mountains constitute an extremely fragile ecological system. They are the youngest mountains in the world and, therefore, highly erodible. They are lashed by rainstorms of an intensity that probably no other mountain system faces. They are extremely seismic, periodically witnessing some of the world's worst earthquakes. Water and silt, therefore, move out of these mountains in explosive waves. Floods and shifting of river courses is, therefore, inevitable.

Deforestation can aggravate the problem but afforestation cannot get rid of it. Now this may not be true of other flood plains with different watershed characteristics, hydrological conditions, rainfall parameters and other ecological characteristics. In fact, the information presented in this report leads us to the inevitable conclusion that the societal susceptibility to the flood problem in the Indo-Gangetic plains has increased more because of the enormous social and ecological changes that have taken place in the flood plains than the changes that have taken place in the higher reaches of the Himalayan watersheds.

We are happy to present this report, in particular, for yet another reason. This is because this is one of the first reports on the ecological change taking place in the Indo-Gangetic plains — an area which supports more people than probably any other in the world and where poverty, inequality and violence are intense. Politics in the Indo-Gangetic plains makes or breaks the government of the whole country. Environmentalists have normally focussed more on the mountains and dry areas. This report should help activists

and analysts to understand the ecological setting of the politics and the society of this extremely important region of India. If environmentally sound development strategies can be developed for this region, currently mired in poverty, destitution and intense inequality, the face of this entire country and its poorest people can change.

Writing this report has, therefore, been an extremely fascinating exercise. Scientifically, it was fascinating to understand the ecological linkages between the extraordinary highlands constituted by the massive Himalayan mountains and the vast, extremely fertile lowlands constituted by the Indo-Gangetic plains. In social terms, the study provided us with some insight into the causes of violence and poverty that continue to stalk this region.

Numerous people have participated in the production of this report. The work started with a field trip by Neeraj Labh, who had just left the Jawaharlal Nehru University, to the flood plains of North Bihar. This was supplemented by more information from the Assam plains brought back by V. Arivudai Nambi, who was earlier an activist working with Save the Eastern Ghats Organisation in Tamil Nadu. Neeraj also spent considerable time researching the highland-lowland linkages in the case of North Bihar plains. Information on the diaras of Bihar was provided by Mukul Sharma of the Navbharat Times, who is now one of India's leading environmental journalists. Mukul had undertaken a fellowship from CSE to study the travails of this region. Sangeeta Synghal, a young journalist, joined us briefly to help in the preparation and improvement of numerous chapters and boxes in this report. Ajit Chak's contribution has been invaluable in the editing of the book, in making it presentable and finally 'laying it to bed', as they say in journalistic circles.

Each one of these people received enormous help from numerous people across the country. Wherever they went, they were received with open arms, information and support. This report could not have been completed without the interest of these people.

We must also thank our readers for the support that they have consistently given us. It is that support alone which has given us the will to persevere. We hope our readers will appreciate the State of India's Environment reports in their new format and will find them equally interesting and useful.

Comments, as before, would always be extremely welcome.

Anil Agarwal
Sunita Narain
Series Editors

- *India is the most flood affected country in the world after Bangladesh.*

- *India accounted for one-fifth of the global death count due to floods from the 1960s to the 1980s. Over 30 million people were displaced annually.*

- *Annual flood damages increased nearly 40 times from an average of Rs 60 crore a year during the 1950s to an incredible Rs 2,307 crore a year during the 1980s. The flood affected area shot up from an average of 6.4 million hectares a year in the 1950s to nine million hectares a year in the 1980s.*

- *Flood relief expenditure more than doubled from Rs 230 crore in 1980-81 to Rs 567 crore in 1985-86 with Uttar Pradesh, Bihar and Orissa figuring regularly in the list as major beneficiaries.*

- *The five most flood prone states are Uttar Pradesh, Bihar, West Bengal, Assam and Orissa. But of late floods have also begun to be serious in Andhra Pradesh, Rajasthan, Haryana and Gujarat.*

- *Official data on floods is hard to get and it is full of discrepancies — almost as if there is a deliberate exercise in disinformation.*

- *Floods are social disasters which affect the poor more than the rich. One disaster makes the poor more vulnerable to the next and converts a disaster into a disaster process.*

- *Government flood control measures mainly consist of dams and embankments. Over 400 km of embankments have been built annually since 1954.*

- *In all 256 large dams, with an average height of 15 metres and above, had been constructed by 1986 and 154 more were under construction.*

- *All these efforts have failed to control floods. Dams have become an important cause of floods. Embankments have disrupted the natural drainage system in the flood plains.*

CHAPTER 1

Pandemonium in the Plains

Natural disasters in India have ranged from rampaging floods, when rivers have sought to extend their watery grip over large land areas, to scorching droughts, which have left in their wake festering sores upon once fertile lands. Floods, however, have visited the country more frequently.

While floods are a phenomenon older than the cities that exist on the banks of the rivers in the Indo-Gangetic plain and the art of flood control is an ancient one in India, large scale measures to control floods were only undertaken after independence and that, too, after the floods in Bihar in 1954.

Stress has remained on engineering responses like dams and embankments, which have necessitated expenditure in astronomical terms. However, a corresponding jump in flood relief expenditure and an alarming increase in flood affected area, despite protection, makes it patently obvious that flood control measures have failed to deliver the goods.

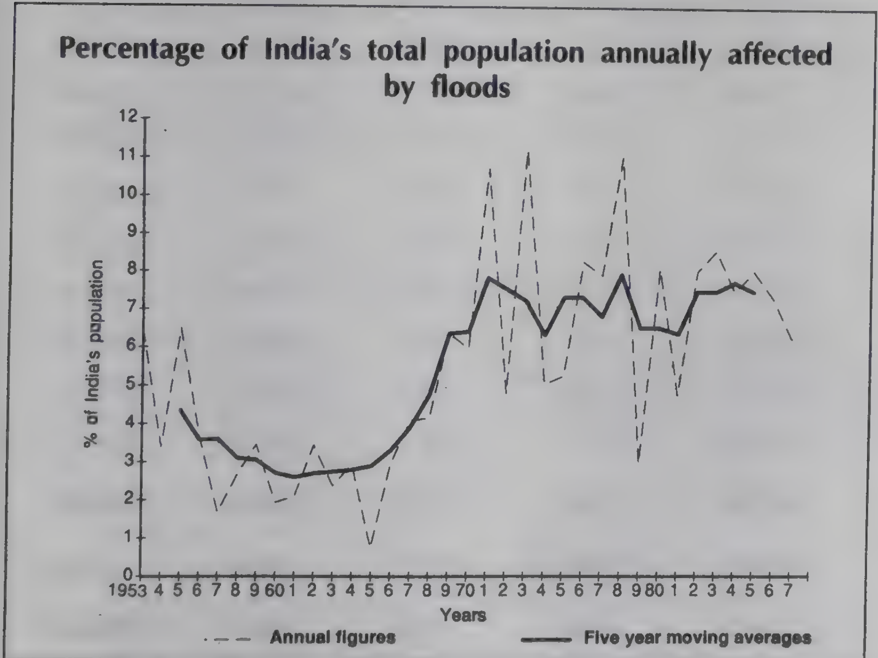
Floods are a major cause of human misery in India every year. Out of the 96 internationally recognised natural disasters the country experienced between 1960 and 1981, 28 were floods, earning the nation the unhappy distinction of being the most flood affected country after Bangladesh. These natural disasters claimed about 60,000 lives with 15,000 people perishing in floods alone, accounting for about 20 per cent of the global death count. Only Bangladesh had a higher proportion of flood related deaths, over 50 per cent of the global total[1].

Indian official statistics display a worse picture. Between 1953 and 1987, some 50,374 people died in floods, an average of about 1,500 deaths annually. During the same period, floods affected an average of 7.66 million hectare (mha), destroyed crops in over 3.51 mha, affected 31.84 million people, damaged 1.2 million houses, killed 0.1 million cattle and caused damages to crops, houses and public property worth Rs 768 crore per year (see table 1)[2].

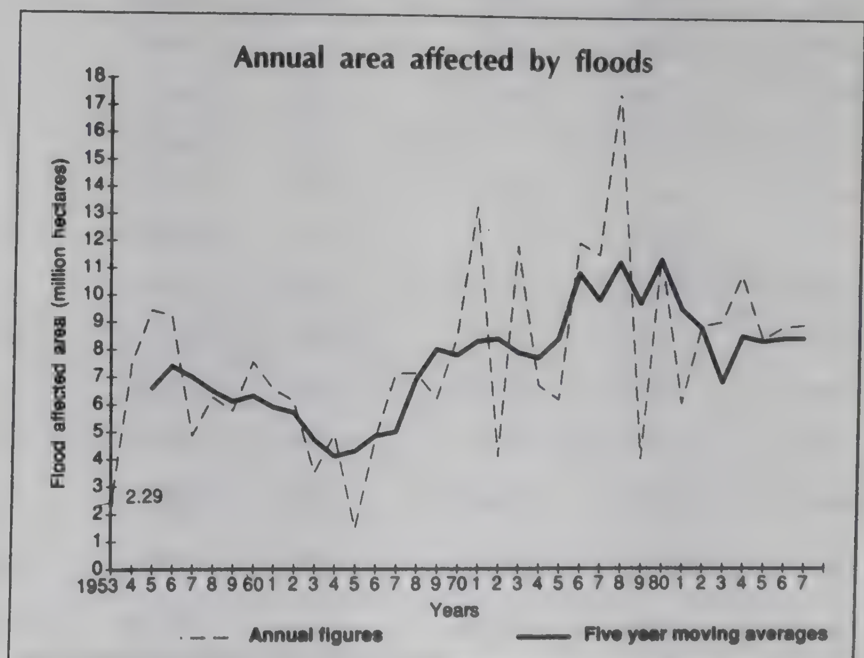
Floods, which are often described as natural disasters, turn out to be social disasters as well, tending to choose their victims by class. It is usually the poor who are severely affected because they live on the periphery of the human habitat. An event, which would not result in the loss of many lives in the affluent North, often results in a major disaster, when it takes place in a country of the South. One disaster makes the poor more vulnerable to the next and, in this way, converts a disaster into a disaster process.

FLOOD INCIDENCE

Global statistics show that over five million people were affected by internationally recognised floods every year during the 1960s and this figure trebled to over 15 million



The annually flood affected population has risen from 16 million in the 1950s to 53 million in the 1980s, much faster than India's population.



The annual area affected by floods rose from 6.48 mha to over nine mha between the 1950s and the 1980s.

Table 1
Flood damages in India during 1953 to 1987 (using published sources)

Year	Area affected (mha)	Population affected (m)	Damage to crops: Area (mha)	Damage to crops: Value (Rs crore)	Damage to houses: Nos. (m)	Damage to houses: Value (Rs crore)	Cattle lost Nos. (m)	Human lives lost Nos.	Damage to public utilities (Rs crore)	Total damage to crops, houses & public utilities (Rs crore)
1953	2.29	24.28	0.93	42.08	0.27	7.42	0.05	37	2.90	52.40
1954	7.49	12.92	2.61	40.52	0.20	6.56	0.02	279	10.16	57.24
1955	9.44	25.27	5.31	77.80	1.70	20.95	0.07	865	3.98	102.73
1956	9.24	14.57	1.11	44.44	0.73	8.05	0.02	462	1.15	53.64
1957	4.86	6.76	0.45	14.12	0.32	4.98	0.01	352	4.28	23.38
1958	6.26	10.98	1.40	38.28	0.38	3.90	0.02	389	1.80	43.97
1959	5.77	14.52	1.54	56.76	0.65	9.42	0.07	619	20.02	86.20
1960	7.53	8.35	2.27	42.55	0.61	14.31	0.01	510	6.32	63.17
1961	6.56	9.26	1.97	24.04	0.53	0.89	0.02	1374	6.44	31.37
1962	6.12	15.46	3.39	83.18	0.51	10.66	0.04	348	1.06	94.89
1963	3.49	10.93	2.05	30.17	0.42	3.70	0.00	432	2.75	36.62
1964	4.90	13.78	2.49	56.87	0.26	4.59	0.00	690	5.15	66.61
1965	1.46	3.61	0.27	5.87	0.11	0.20	0.01	79	1.07	7.13
1966	4.74	14.40	2.16	80.15	0.22	2.54	0.01	180	5.74	88.43
1967	7.12	20.46	3.27	133.31	0.57	14.26	0.01	355	7.86	155.43
1968	7.15	21.17	2.62	144.61	0.68	41.11	0.13	3497	25.37	211.09
1969	6.20	33.22	2.91	281.89	1.27	54.42	0.27	1408	68.11	404.43
1970	8.46	31.83	4.91	162.78	1.43	48.61	0.02	1076	76.44	287.83
1971	13.25	59.74	6.24	423.13	2.43	80.24	0.01	994	129.11	632.48
1972	4.10	26.69	2.45	98.56	0.90	12.46	0.06	544	47.17	158.19
1973	11.79	64.08	3.73	428.03	0.87	52.48	0.26	1349	88.49	569.00
1974	6.70	29.45	3.33	411.64	0.75	72.43	0.02	387	84.94	569.01
1975	6.17	31.36	3.85	271.49	0.80	34.09	0.02	686	166.05	471.63
1976	11.91	50.46	6.04	595.03	1.75	92.16	0.08	1373	201.50	888.68
1977	11.46	49.43	6.84	720.61	1.66	152.29	0.56	11316	328.95	1201.84
1978	17.53	70.45	9.96	911.08	3.51	167.57	0.24	3396	376.10	1454.76
1979	3.99	19.52	2.17	169.97	1.33	210.61	0.62	3637	233.63	614.21
1980	11.46	54.12	5.55	366.37	2.53	170.85	0.06	1913	303.28	840.50
1981	6.02	32.49	3.27	524.56	0.91	159.63	0.09	1376	512.31	1196.51
1982	8.87	56.01	5.00	589.40	2.40	383.87	0.25	1573	671.61	1644.87
1983	9.02	61.03	3.29	1285.85	2.39	332.33	0.15	2378	873.43	2491.60
1984	10.71	54.55	5.19	906.09	1.76	181.31	0.14	1661	818.16	1905.56
1985	8.38	59.59	4.65	1425.37	2.45	583.86	0.04	1804	2050.03	4059.25
1986	8.81	55.52	4.58	1231.58	2.05	534.41	0.06	1200	1982.54	3748.52
1987	8.88	48.34	4.94	1154.64	2.92	464.49	0.13	1835	950.59	2569.72
Worst	**17.53**	**70.45**	**9.96**	**1425.37**	**3.51**	**583.86**	**0.62**	**11316**	**2050.03**	**4059.25**
Year	**(1978)**	**(1978)**	**(1978)**	**(1985)**	**(1978)**	**(1985)**	**(1979)**	**(1977)**	**(1985)**	**(1985)**
Annual Average	**7.66**	**31.84**	**3.51**	**367.79**	**1.21**	**112.62**	**0.10**	**1439**	**287.67**	**768.08**

Source: 2

PREDICAMENT OF PLENTY: Women wade out of a marooned village in search of water. Villages face acute drinking water scarcity in times of floods as wells and ponds get flooded with dirty water. (UNI)

in the 1970s. India's official statistics reveal that the average flood affected population per year increased from about 16 million in the 1950s to 43 million in the 1970s and 53 million in the 1980s. The annual flood affected population has, in fact, risen faster than India's population (see figure 1). Simultaneously, affected areas, damages and relief expenditure also went up steadily (see table 3).

Flood relief

Flood relief expenditure rose from Rs 230 crore in 1980-81 to Rs 567 crore in 1985-86 (see table 4)[3]. Relief expenditure during the Sixth plan (1980-85) was more than that on planned flood control programmes. About three-quarters of the annual flood relief provided by the Central government goes to about three to six states a year. Uttar Pradesh, Bihar and Orissa figure regularly in the list of major beneficiaries.

However, the increase in relief expenditure by the Central government may not be a good indicator of increasing floods incidence. The constant complaint of state governments that Centre-State distribution of national revenue is extremely lopsided, has led to a tendency amongst the states to demand as much Central assistance for disaster relief as possible. The amount of money sought is often more than the total plan expenditure of the states concerned. The number of states demanding Central relief assistance has gone up from about eight to 10 states a year to almost all the states now[4]. The amount provided by the Central government often becomes a politically contentious issue, especially when the party ruling a flood affected state is in opposition at the Centre.

Flood damages

Apart from flood relief expenditures, flood damage figures have also been steadily increasing. The average annual damage to crops, houses and public property was of the order of Rs 60 crore during the 1950s. This figure increased 38 times to a whopping Rs 2,307 crore per year during the 1980s. Average annual crop damages increased from Rs 45 crore in the 1950s to Rs 935 crore in the 1980s (see table 3). Some of this increase is definitely the result of inflation and increasing population, encroachment of the flood plains and investment in agriculture as well as other activities in the flood plains.

Until the 1970s, crop damages on an average accounted

Table 2

Flood damages and population affected per hectare of flood affected area

Decade		Population affected/ total area affected by floods	Crop damages/ crop area affected (Rs/ha)	Total damages/ total area affected (Rs/ha)
1950s	(1953-59)	2.47	235	93
1960s	(1960-69)	2.71	377	210
1970s	(1970-79)	4.51	847	717
1980s	(1980-87)	5.88	2051	2557

Source : 2

for three-quarters or more of the total. But in the 1980s, this dropped sharply to less than half. This indicates greater non-agricultural investment in the flood plains. The number of persons affected per hectare of flood affected area went up sharply from less than three in the 1950s and 1960s to nearly six in the 1980s (see table 2). This is definitely an indication of increasing population and encroachment of the flood plains. The average crop area affected annually has increased sharply from less than two mha in the 1950s to over 4.5 mha in the 1970s and 1980s. The proportion of cropped area to total area affected by floods rose from about 30 per cent in the 1950s to slightly over 50 per cent in the 1970s and 1980s. During the 1950s and 1960s, the country's cultivated area increased rapidly — from about 119 mha in 1950-51 to 141 mha in 1970-71 — but has remained relatively stationary since then. This indicates that the cultivated area extended deeper into the flood plains during the 1950s and 1960s.

Table 3

Trends in flood affected population, area and damages (using published CWC sources)

Decade		Average annual area affected by floods (mha)	Average annual crop area affected: Actual (mha)	% of total area affected by floods (%)	% of country's net sown area (%)	Average annual flood affected population: Actual (m)	% of total population (%)	Average annual total flood damages (Rs crore)	Average annual crop damages: Actual (Rs crore)	% of total flood damages (%)
1950s	(1953-59)	6.48	1.91	29	1.47	16	4.03	59.94	44.86	75
1960s	(1960-69)	5.53	2.34	42	1.71	15	3.13	115.92	88.26	76
1970s	(1970-79)	9.54	4.95	52	3.51	43	7.18	684.76	419.23	61
1980s	(1980-87)	9.02	4.56	51	3.18	53	7.26	2307.07	935.48	41

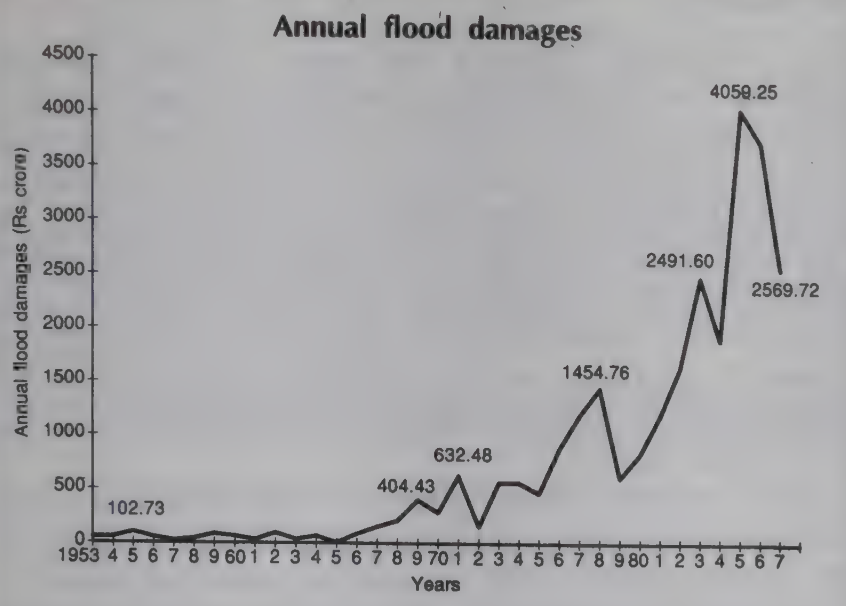
Source : 2, 16, 17, 18

Table 3a

Trends in flood affected population, area and damages (using unpublished CWC sources)

Decade		Average annual area affected by floods (mha)	Average annual crop area affected: Actual (mha)	% of total area affected by floods (%)	% of country's net sown area (%)	Average annual flood affected population: Actual (m)	% of total population (%)	Average annual total flood damages (Rs crore)	Average annual crop damages: Actual (Rs crore)	% of total flood damages (%)
1950s	(1953-59)	6.86	2.08	30.32	1.60	17.50	4.41	62.33	45.48	73
1960s	(1960-69)	5.86	2.47	42.15	1.80	15.45	3.25	104.14	77.68	75
1970s	(1970-79)	11.19	5.55	49.60	3.99	43.35	7.18	674.09	419.06	62
1980s	(1980-84)	16.57	6.91	41.70	4.90	53.01	7.26	1590.43	713.95	45

Source : 6, 16, 17, 18



Source : 2, 16, 17, 18

Average annual flood damages were only Rs 60 crore in the 1950s. They became a staggering Rs 2,307 crore during the 1980s.

Flood prone area

The most clinching evidence of floods having increased as a physical phenomenon comes from the increase in the flood affected area. The flood affected area increased from an annual average of 6.48 mha in the 1950s to over nine mha in the 1970s and 1980s. This increase is definitely an indication of the country's growing flood proneness.

The Rashtriya Barh Ayog (RBA) or National Commission on Floods, set up by the government in 1976, because of the growing public concern over increasing floods, first provided statistical evidence of the problem. The commission took the maximum area affected by floods in a state, in any year, as its flood prone area and in this way added up the flood prone areas of all the states to get the flood prone area of the country[5]. This method underestimates the problem because there is no guarantee that floods in any year will affect only those areas which were affected during the maximum flood year. Yet the commission found that the country's flood prone area which had been estimated at

Table 4

Central assistance sanctioned as relief for floods etc.

Year	Total natural disaster relief (Rs crore)	Flood, snowstorm, cyclone etc relief (Rs crore)	Flood relief as percentage of total disaster relief (%)	States which together got nearly or over 75 per cent of the flood relief money
1980-81	494.11	229.88	47	Uttar Pradesh, Orissa, Bihar, West Bengal
1981-82	338.75	148.69	44	Uttar Pradesh, Rajasthan, Bihar
1982-83	807.96	359.02	44	Orissa, Gujarat, Uttar Pradesh
1983-84	646.56	351.86	54	Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Gujarat, Maharashtra
1984-85	496.59	321.16	65	Uttar Pradesh, West Bengal, Assam, Bihar, Andhra Pradesh, Tamil Nadu
1985-86	1035.26	567.45	55	Uttar Pradesh, Kerala, Tamil Nadu, Punjab, Orissa
1986-87	1023.87	430.90	42	Andhra Pradesh, Uttar Pradesh, West Bengal, Assam, Kerala, Jammu and Kashmir

Source: 3 and 19 for 1986-87

Table 4a

Central assistance sought and received by states for floods

States	1982-83 to 1986-87	
	Assistance sought (Rs crore)	Ceiling approved by central government (Rs crore)
Uttar Pradesh	3567.74	386.75
Andhra Pradesh	1785.53	278.92
Orissa	1228.48	258.39
Kerala	1178.45	182.90
Assam	661.02	115.75
Punjab	551.84	78.96
Bihar	537.05	113.36
Gujarat	466.87	166.58
West Bengal	459.31	102.24
Tamil Nadu	417.91	136.99
Himachal Pradesh	357.66	44.15
Madhya Pradesh	190.65	22.40
Haryana	185.89	28.86
Maharashtra	162.34	44.88
Rajasthan	130.69	22.99
Sikkim	105.62	13.36
Jammu and Kashmir	100.62	26.70
Tripura	45.79	17.92
Karnataka	39.79	7.72
Meghalaya	23.12	8.52
Manipur	19.43	3.84
Nagaland	5.95	1.01
All India	12221.75	2013.19

Source : 19

Flood prone areas

The Rashtriya Barh Ayog estimates the country's flood prone area at 40 mha. But it may be even higher.

about 25 mha during the 1960s went up sharply to 34 mha by 1978. Since 10 mha had been covered by flood protection measures by then ∇ it is well known that these measures often fail during high floods ∇ the commission put the country's flood prone area at about 40 mha. This report, thus, revealed a rapid increase in flood proneness in just over a decade.

The most flood prone basins are those of the Ganga and the Brahmaputra in Uttar Pradesh, Bihar, West Bengal and Assam, followed by Baitarni, Brahmani and Subarnarekha basins in Orissa. These five states are the most flood prone. But the commission, analysing flood damages in the late 1970s, pointed out that during the period 1976-78, floods were also experienced in Andhra Pradesh, Rajasthan, Haryana and Gujarat, that is, "in areas not usually affected." The share of damages of the second group went up from around 20-25 per cent to about 50 per cent of the total. Even in the chronically flood prone Uttar Pradesh and Bihar, the flood affected area has been increasing.

The commission did not find any evidence to show that rainfall had increased during the 1970s. The commission, therefore, felt that floods had increased more because of human factors like deforestation; drainage congestion caused by badly planned construction of bridges, roads, railway tracks and other developmental activities; reduction in infiltration because of increased occupation of land by industries and large scale urbanisation; and, construction of embankments along rivers. Apart from inflation, damages increased because of the increased flood incidence and encroachment of the flood plains.

The statistics

The commission's report is now over a decade old. To calculate the latest flood prone area of the country, researchers must have access to the annual flood affected area of every state. Unfortunately, this data is not easily available from the Central Water Commission (CWC). In early 1987, the Centre for Science and Environment (CSE) obtained detailed statewise data on flood affected areas for the period 1953 to 1984 from a government agency which claimed that CWC was its original source[6]. The data obtained by CSE match the data used by the RBA from 1953 to 1976 (see table 7).

When analysed, the data shows that the flood prone area has risen even further. In 1969 it was 23 mha; in 1979, it was 49 mha; and, in 1984, it was 58.5 mha (see table 5). Since the RBA method underestimates the flood prone area and the commission had also pointed out that a large portion of the flood protected area is liable to get flooded, the total flood prone area of the country, according to the latest data, should now be well over 60 mha, about one-fifth of India's land area.

But the CWC disputes this. According to its estimate presented to the Working Group on Flood Management for the Eighth plan[7], the area in 1978 was 34.65 mha and, by 1988, it had merely increased to 36.66 mha (see table 6). The ministry of water resources believes that the area is about one-eighth of the country.

A comparison of the statistics on the annual nationwide flood affected areas published by CWC's statistics directorate, the data used by the RBA, and that obtained by CSE shows wide variations. While the last two sources show the same data from 1953 to 1976, the data published by CWC is very different. The differences reveal an interesting trend in the variations ∇ the CWC data is on the higher side in many years during the 1950s and 1960s whereas it is lower during the 1970s and 1980s. In some cases, there is a difference of as much as five mha in one year! CSE has not been able

Flood prone river basins

The most flood prone basins are those of the Ganga in Uttar Pradesh, Bihar and West Bengal and Brahmaputra in Assam followed by those of Baitarni, Brahmani and Subarnarekha in Orissa.

to get statewise data directly from CWC.

A senior CWC official told CSE in 1987 that the latter's calculation of the country's flood prone area, presented in a lecture to the members of Parliament at the request of the then Prime Minister, Rajiv Gandhi, is not correct. The CWC claims that the data presented by the states tends to exaggerate the area affected. To get a better estimate, the area damaged by cyclones or waterlogging caused by heavy rains has to be subtracted. *Floods are strictly defined as the overflowing of a river.*

The official also pointed out that the increase indicated by the RBA is not one in reality. The 1960s figure of 25 mha used by the RBA was an underestimate because it was based on data collected during the 1950s and 1960s. The data sample was, therefore, very small. As years went by and more data became available, the true flood prone area revealed itself, which seems to be about 40 mha. In other words, the area was always about 40 mha, according to the CWC. And, because it disregards the inconvenient data of the 1980s, this has remained more or less the same.

The discrepancy

It, however, remains to be answered how the data used by the RBA from 1953 to 1978 (provided to it by the CWC)

Table 5

Flood prone area of India (using unpublished CWC sources)

States	Maximum flood area affected			
	1953-59 (mha)	1953-69 (mha)	1953-79 (mha)	1953-84 (mha)
Andhra Pradesh	1.39	1.45	5.98	5.98
Arunachal Pradesh	-	-	Neg	Neg
Assam	3.15	3.15	3.15	3.15
Bihar	2.50	2.50	4.26	4.26
Goa	-	-	-	-
Gujarat	1.39	1.39	1.39	3.04
Haryana	0.34	0.36	1.00	1.00
Himachal Pradesh	0.23	0.23	0.23	0.23
Jammu and Kashmir	0.08	0.08	0.08	0.08
Karnataka	-	0.01	0.20	0.26
Kerala	0.29	2.00	2.00	2.00
Madhya Pradesh	0.26	0.26	5.17	5.17
Maharashtra	0.23	0.23	0.74	1.13
Manipur	0.01	0.08	0.08	0.08
Meghalaya	-	-	0.02	0.54
Mizoram	-	-	Neg	Neg
Nagaland	-	-	-	Neg
Orissa	1.20	1.40	2.97	9.00
Punjab	0.99	1.73	1.73	1.73
Rajasthan	0.03	0.53	3.26	3.26
Sikkim	-	-	Neg	0.02
Tamil Nadu	0.03	0.45	0.45	5.66
Tripura	0.04	0.33	0.33	1.50
Uttar Pradesh	4.13	4.13	7.34	7.34
West Bengal	2.65	2.65	3.08	3.08
Flood prone area	18.94	22.96	43.46	58.51

Source : 6

Table 6

Flood prone area of India (CWC)

States	Flood prone area	
	1953-78 (mha)	1953-88 (mha)
Andhra Pradesh	1.39	1.39
Arunachal Pradesh	-	0.00
Assam	3.15	3.82
Bihar	4.26	4.26
Goa	-	0.00
Gujarat	1.39	1.39
Haryana	2.35	2.35
Himachal Pradesh	0.23	0.39
Jammu and Kashmir	0.08	0.51
Karnataka	0.02	0.26
Kerala	0.87	0.87
Madhya Pradesh	0.26	0.26
Maharashtra	0.23	0.23
Manipur	0.08	0.08
Meghalaya	0.02	0.10
Mizoram	-	0.00
Nagaland	-	0.01
Orissa	1.40	1.40
Punjab	3.70	4.05
Rajasthan	3.26	3.26
Sikkim	-	0.02
Tamil Nadu	0.45	0.45
Tripura	0.33	0.33
Uttar Pradesh	7.34	7.34
West Bengal	3.77	3.77
Delhi	0.07	0.07
Pondicherry and other UTs	0.01	0.05
Flood prone area	34.65	36.66

Source : 7

is so different from that published by the CWC itself. The CWC does not express any doubts about the data used by the commission yet the latest CWC data for 1976 and 1977 is 5.98 mha and 5.92 mha less than the data used by the RBA. The flood affected area presented by CWC for 1982 and the data obtained by CSE show a difference of as much as 19.24 mha (see table 7). The average flood affected area shows an even more dramatic rise between the 1950s and 1980s, if the latter data are used (see table 3a). Clearly, there is a serious discrepancy lurking somewhere.

Table 7

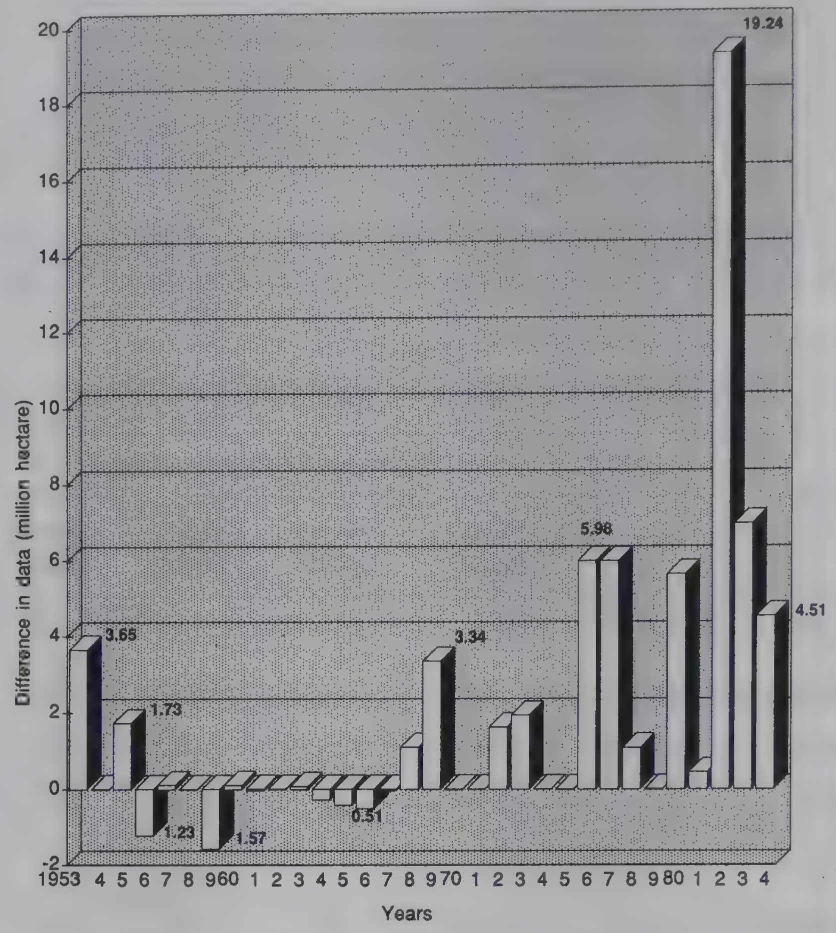
Differences in official statistics on flood affected areas

Years	CWC published data (mha)	RBA[1] (mha)	Differences between RBA and CWC published data (mha)	CWC unpublished data (mha)	Differences between unpublished and CWC published data (mha)
1953	2.29	5.94	3.65	5.94	3.65
1954	7.49	7.48	-0.01	7.48	-0.01
1955	9.44	11.17	1.73	11.17	1.73
1956	9.24	8.01	-1.23	8.01	-1.23
1957	4.86	4.97	0.11	4.97	0.11
1958	6.26	6.24	-0.02	6.24	-0.02
1959	5.77	4.20	-1.57	4.20	-1.57
1960	7.53	7.63	0.10	7.63	0.10
1961	6.56	6.53	-0.03	6.53	-0.03
1962	6.12	6.12	0.00	6.12	0.00
1963	3.49	3.56	0.07	3.56	0.07
1964	4.90	4.62	-0.28	4.62	-0.28
1965	1.46	1.04	-0.42	1.04	-0.42
1966	4.74	4.23	-0.51	4.23	-0.51
1967	7.12	7.08	-0.04	7.08	-0.04
1968	7.15	8.25	1.10	8.25	1.10
1969	6.20	9.54	3.34	9.54	3.34
1970	8.46	8.45	-0.01	8.45	-0.01
1971	13.25	13.25	0.00	13.25	0.00
1972	4.10	5.72	1.62	5.72	1.62
1973	11.79	13.72	1.93	13.72	1.93
1974	6.70	6.70	0.00	6.70	0.00
1975	6.17	6.15	-0.02	6.15	-0.02
1976	11.91	17.89	5.98	17.89	5.98
1977	11.46	17.38	5.92	17.43	5.97
1978	17.53	17.44	-0.09	18.61	1.08
1979	3.99			3.98	-0.01
1980	11.46			17.08	5.62
1981	6.02			6.46	0.44
1982	8.87			28.11	19.24
1983	9.02			15.98	6.96
1984	10.71			15.22	4.51
1985	8.38				
1986	8.81				
1987	8.89				

Note : [1] RBA also obtained its data from CWC.

Source : 2,5,6

Difference between CWC published and CWC unpublished data



The CWC published data on annually flood affected area is on the higher side in many years during the 1950s and 1960s whereas it is on the lower side during the 1970s and 1980s, when the flood affected area rose dramatically. Is this a deliberate attempt to play down the area affected by floods in recent years?

The nonchalance with which data is handed out by the ministry of water resources has been criticised by economist Arun Ghosh, an ex-member of the Planning Commission. Says Ghosh: "According to the RBA, the total area subject to periodic floods has doubled in 10 years. But such facts are glossed over in the annual report of the ministry of water resources. Roughly 13 mha are claimed to have been provided reasonable protection through concerted efforts between 1954 and 1985. However, according to the RBA, the area prone to floods has increased. Whom are we to believe ? The officials patting their backs in the annual report of the ministry, or an independent commission appointed by the government ?"[8].

The available data shows that the problem is growing. Even if the conservative CWC data are used, as they have been used for the earlier analysis in this publication, there is still no room for doubt that the problem has grown dramatically, both in terms of area and damages. But exactly to what extent nobody really seems to know. And those who should, seem to be bent on keeping the public ignorant and spreading disinformation.

Flood Protection Embankments

Heavily embanked areas

Embanked areas of Bihar

Embanked areas of Assam

Between the 1950s and the late 1980s, over 14,500 km of embankments were constructed, of which nearly 4,000 km were constructed in Assam and 3,400 km in Bihar.

HISTORY OF FLOOD CONTROL

Floods are not new to India. The practice of building flood protection embankments along rivers was an ancient one in the Godavari, Krishna and Cauvery deltas and in the Indo-Gangetic plains. However, nationwide flood protection programmes began only after independence.

When the British left, there were some 5,280 km of embankments along different rivers, of which 3,500 km were in the Sundarbans in West Bengal and 1,209 km along the Mahanadi in Orissa, providing protection to a total of about three mha. Not enough attention was paid to flood control measures by the colonial rulers. Committees were appointed from time to time in Assam (1929, 1934 and 1947), Bihar (1926) and West Bengal (1922), but their recommendations were rarely implemented. Investigations carried out by these committees also suffered from a shortage of information regarding the behavior of rivers[5].

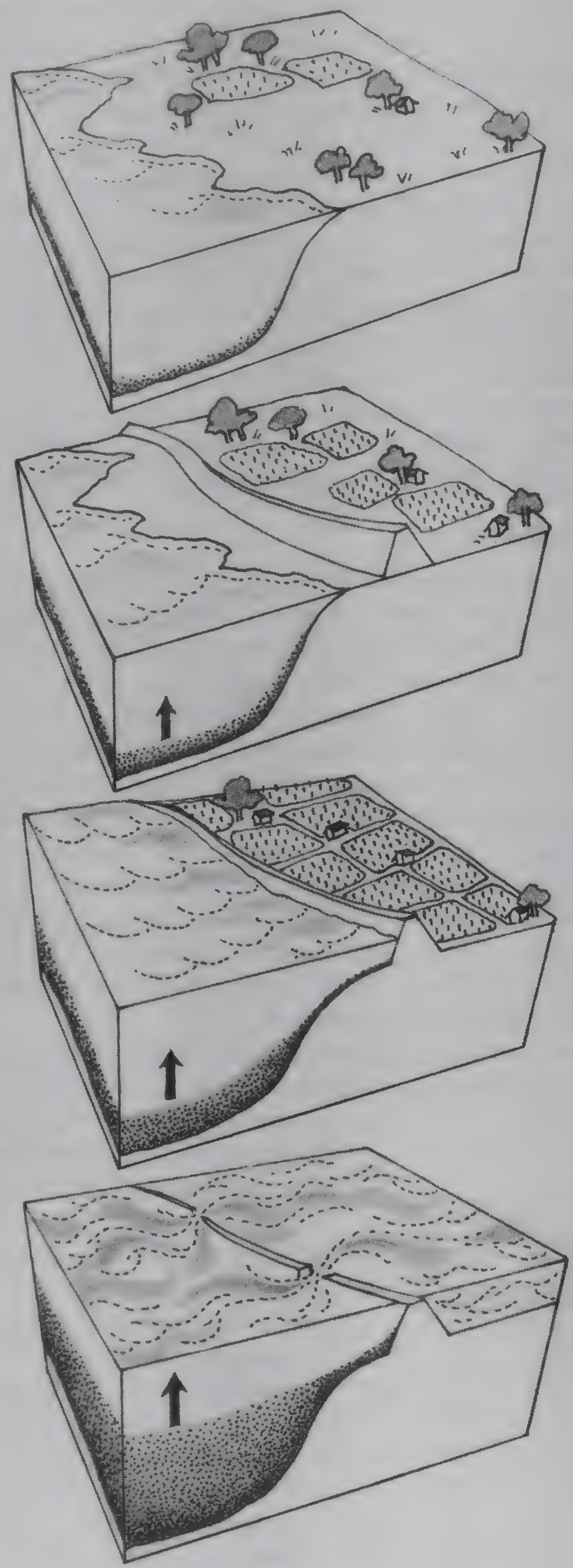
The strategy

The First plan which began in 1951, decided to move away from embankments and put more faith in large dams to store flood waters. The plan document stated that "the construction of large dams to store these flood waters is the most effective way of preventing flood damage." Dams were conceived on the flood prone rivers of Damodar, Mahanadi and Kosi. But even before the plan was half over, the idea of a dam on the Kosi at Barahkshetra in Nepal had to be shelved. The Nepalese government remained lukewarm towards the project. The proposed site was also located too close to the epicentre of an earlier major earthquake[9]. As a result, stress once again shifted to embankments, especially in north Bihar, while dams were constructed on the Damodar and Mahanadi.

In 1954, came a spate of severe floods — one of the worst — in the country. All northern rivers flooded simultaneously and led to enormous devastation across Uttar Pradesh, Bihar, West Bengal and Assam. The severe floods attracted public attention to the inadequacy of flood control measures.

The leadership of a newly independent country, with its immense faith in modern technology, immediately promised the nation that it was possible to be rid of this menace. A national policy statement on flood problems and remedies was put before Parliament which claimed: "*floods in the country can be contained and managed* (emphasis ours Ed). The administration and the people have both to undertake tasks of a huge magnitude in order that the country may be rid of the menace of floods."

Social impact of embankments



Embankments encourage human occupation of the flood plains by instiling a false sense of security. When rivers in spate breach the embankments a tidal wave hits the villages nearby.

EMBANKMENT ILLS

Construction of embankments worsens the problem of floods over time, the common negative effects being:

Reduced passage

By confining the flood waters to the river channel and a small part of the flood plains, embankments, in case of a river whose bed is rising, force the sediment load, which would earlier have been deposited over a much wider area of the flood plains,to be deposited within the embanked area. This results in higher flood levels, and may also lead to a breach in the embankment. Thus to give the level of protection initially envisaged, progressive raising of the embankment becomes inevitable. A vicious race then commences between the rise of the river bed and the raising of the embankment.

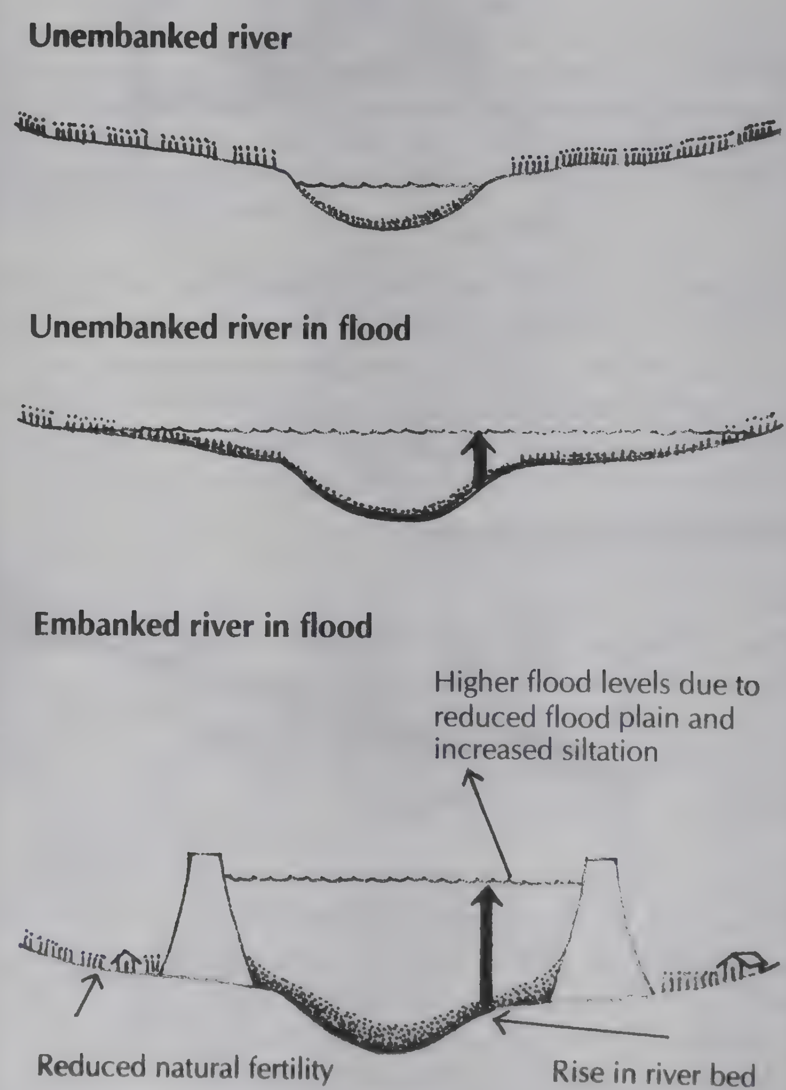
Reduced natural fertility

This process further deprives the wider flood plains of the rich silt deposits left behind by receding flood waters, traditionally an important source of fertility enrichment in the flood plains.

Build up of flood waters

By constricting the river's natural flood plains, embankments lead to a dangerous build up of high flood levels within the embanked area. At the same time they tend to engender a false sense of security in the people inhabiting the surrounding flood plains. Thus, in case of a breach, the flood waters literally

Ecological effects of embankments



cascade upon the surrounding countryside adding considerably to the magnitude and reach of their devastating potential.

Drainage congestion

The construction of embankments cuts off the natural drainage from the flood protected areas into the river except through predetermined drainage sluices provided in the embankment. The capacity of the artificial drainage sluices is never equal to the previous waterways available for natural drainage into the river. The problem of drainage congestion, therefore, gets aggravated in the flood protected area. The Rashtriya Barh Ayog (RBA) report states, "Embankments are not a feasible measure of flood protection in cases where the country runoff draining into the river is so large as to inundate appreciatively the area protected by the embankments from river spills, during periods when the river is running at high flood stages."

Drainage congestion becomes still more acute in cases where tributaries join the main river along which embankments have been provided. Tributaries with large catchment areas may carry considerable discharges, which are difficult to accommodate in sluices. In such conditions, engineers usually respond with sympathetic or back embankments along the tributary so that the flood water of the main river cannot inundate the countryside by flowing up the tributary and spilling along its bank. But at the junction of the back embankment and the main embankment — particularly the upstream junction — drainage congestion becomes an acute problem. Huge quantities of water can collect at such junctions.

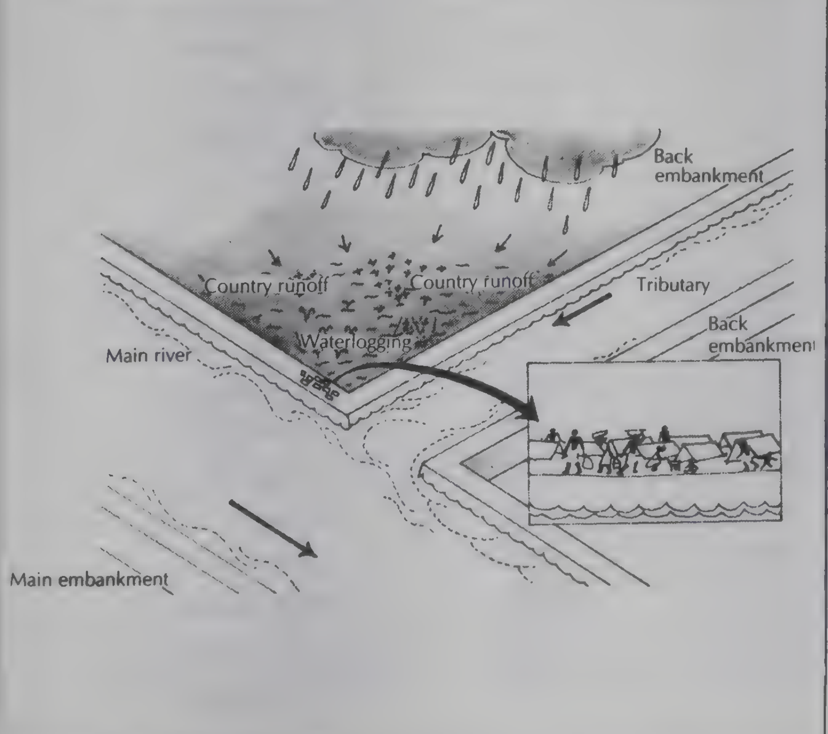
Waterlogging

In the case of a river, whose bed is rising rapidly after embanking, the water level can reach a point that it remains higher than the surrounding countryside throughout the year. In such conditions, the flood protected area along the embankment will get waterlogged.

River attacks due to shifting courses

A shifting river can make unexpected erosion attacks on embankments and necessitate expensive responses.

Drainage congestion at the junction of embankments



The government visualised a mass popular upsurge to construct embankments creating in the process employment for millions. The policy statement noted: "Provided the enthusiasm of the people can be aroused, as it is stated to have been in China, and their cooperation secured for this work of national importance, it would be possible to complete work on embankments in about seven years if a start is made immediately. The programme of flood protection work will incidentally provide, on a tremendous scale, opportunities for employment of a simple character, scattered over large areas. Although embankments do not provide absolute immunity from the floods, they will ensure a very large measure of protection, which, given good maintenance, should prove to be of a lasting character"[5].

The programme

A three phased programme was proposed. During the immediate phase, which was to extend over a period of two years, protection of certain towns and construction of embankments in areas requiring urgent attention were to be undertaken. Simultaneously, scientific and economic investigations were to be undertaken for short term measures, which would begin with the Second plan. These measures involved the building of more embankments, channel improvements, raising of villages and protection of towns. The long term phase involved the construction of dams and additional embankments wherever necessary. Central and state flood control boards were set up in order to implement the programme. The state governments were given the key responsibility to undertake flood control measures.

But this programme did not go very far. By 1956, the overly optimistic belief in the idea of getting rid of floods had mellowed. The belief by now was that: 'it is still possible to get rid of floods but it will take time.' The minister for planning, irrigation and power, who was also responsible for flood control told Parliament in 1956, "We cannot expect for years to come to be in the fortunate position of being absolutely immune from flood risks. We shall have to learn to live with floods to an extent. We shall, however, be able to curb and confine the floods, more and more."

By 1956, the technocratic dependence on dams and embankments exhibited in the 1954 policy statement had also begun to change. In 1955, Parliament was told that flood warning and watershed management programmes, some of which had been tried out on an experimental basis in the Kosi catchment, would also be taken up. In 1956, Parliament was again told that drainage channel improvements would also be undertaken.

Thus, within two years of its 1954 policy statement, the government was floundering and backtracking on its initial promise. By February 1957, the government even had to set up a high level committee on floods to contain growing criticism of its programme. The minister said, "Opinion is sharply divided on the suitability of certain measures of flood protection in the shape of embankments. It is important that all such questions should be settled beyond doubt. The government, therefore, proposes to set up a high level committee."

TALL BLUNDERS

The *Register of Large Dams* lists 410 dams of height 15 m and above, completed or under construction, by end 1986. Many of these are supposed to provide multiple benefits like water, electricity and flood control. The report of the Rashtriya Barh Ayog (RBA) points out that flood control is an objective that often gets inadequate priority. Since the economic objectives of generating electricity and providing water are weightier, reservoirs get filled up soon and then retained at a high level. On the contrary, flood moderation requires that reservoir levels be kept as low as possible until the end of the monsoon season. Faced with a late monsoon downpour, say in September or October, dams often have to make panic discharges which can create massive floods downstream, especially as rivers at that time are also brimming with monsoon flows.

The devastating September 1988 floods in Punjab followed exactly this pattern. With late monsoon rains raising the level of an already full Bhakra reservoir to an alarming 537 m, two metres above permissible level, panic discharges from the dam added to streams in full flow and led to a flood that affected vast areas, including Ludhiana, Jalandhar, Amritsar and Bathinda. The floods directly affected over 4.3 million people.

The Bhakra Beas Management Board (BBMB) faced enormous criticism. Punjab's leading daily, *Punjab Kesari*, called it a human made disaster[1] and things reached a head with the killing of the BBMB chairperson, major general B N Kumar, in a terrorist attack. Prior to his killing, the chairperson had insisted that the September deluge was not the responsibility of the BBMB[2]. Bhakra was faced with a similar controversy exactly a decade ago in 1978 when heavy discharges from the reservoir caused floods affecting an estimated 65,000 people in Punjab[3].

The West Bengal floods, where 10 districts and three million people were affected in September 1978, were also attributed to lack of proper maintenance of the Damodar Valley Corporation (DVC) dams. The DVC chairperson, lt general M M Ghai had admitted to declining standards of DVC in flood control. The spill gates of the Tenughat dam connected to the Panchet reservoir by a channel were malfunctioning and they could not hold the monsoon deluge, letting the water flow to Panchet. The Panchet, faced with the huge flow, discharged the excess water leading to the inundation of Howrah, Hooghly and Midnapur districts of West Bengal[4]. A report by former deputy director general of the Geological Survey of India, Subrata Sinha, claims that deforested upper catchment and heavy sedimentation of the reservoirs had reduced the water storage capacity of the reservoirs and, hence, their flood cushioning capacity. The DVC, Mayurakshi and Kangsabati dams transmit the impounded river water through a grid of canals to areas with a high groundwater table. The resulting waterlogged conditions mean that river water cannot seep underground and this aggravates floods[5].

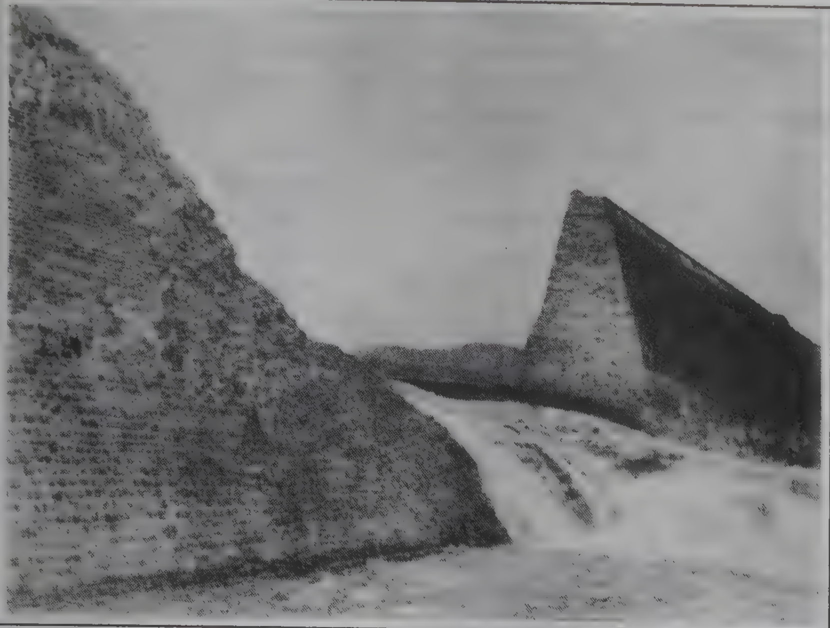
Other instances of dam caused floods are when these massive structures burst in face of inclement rains. The Panchet dam on the river Mutha burst in 1961 causing colossal damage and loss of lives in Pune. Impounding of water before the work on the dam was fully complete was one of the reasons for the disaster[6]. It is the biggest dam to have burst till now. At Morvi in Gujarat, an earth and masonry dam on the river Machhu burst, following heavy rains in August 1979. The six to seven m high tidal wave which swept through Morvi town and the neighbouring talukas left 1,419 people dead[7].

In 1981 a minor irrigation dam in Gopinatham village in Karnataka burst taking a toll of 47 lives. Steady and heavy rains converted a small stream to river size and the normal discharge of the tank doubled and breached the bandh. The resulting tidal wave swept the small hamlet of Gopinatham away with it. A report by the Public Accounts Committee in 1982 pointed out that 70 per cent of the work on the waste weir channel connected to the tank was incomplete, causing the surplus water to get blocked and forcing a breach in the tank[8,9]. According to the ministry of water resources, there have been 16 dam

Total dam collapses in India

State	Name of the project	Type	Maximum height (m)	Year of completion	Year of failure	Cause of failure
Madhya Pradesh	Tigra	Masonry	26.00	1914-17	1917	Overtopping
Maharashtra	Kundali	Masonry	45.00	1924	1925	Structural
Madhya Pradesh	Pagara	Composite	27.03	1911-27	1943	Overtopping
Uttar Pradesh	Lower Khajauri	Composite	16.00	1949	1949	Piping
Uttar Pradesh	Ahraura	Earth	22.40	1954	1955	Piping
Andhra Pradesh	Kaddam	Composite	22.50	1957	1958	Overtopping
Gujarat	Kaila	Earth	26.00	1954	1959	Piping
Maharashtra	Panshet	Earth	53.80	1961	1961	Piping
Bihar	Kharagpur	Earth	24.00	NA.	1961	Overtopping
Maharashtra	Kadakwasla	Masonry	40.00	1875	1961	Overtopping
Madhya Pradesh	Kedarnala	Earth	21.30	1964	1964	Piping
Uttar Pradesh	Nanaksagar	Earth	16.50	1962	1967	Piping
Karnataka	Chikkahole	Masonry	36.81	1969	1972	Structural
Tamil Nadu	Kodaganar	Earth	17.70	1977	1977	Overtopping
Gujarat	Machhu-II	Masonry/Earth	24.69	1972	1979	Overtopping
Gujarat	Mitti	Earth	16.02	1982	1988	Overtopping

Source : 10



TOPPLED MONOLITH: A 30 metre breach in the 85-year-old Khadakwasla masonry dam was caused by the impact of the water that had poured into it following the breach in the Panchet earthern dam on July 12, 1961. The Mutha river is seen flowing through this breach. (B K Vaidya).

bursts in India[10]. But the number will be greater if minor irrigation dams are included. The table attached to the ministerial reply in Parliament does not include the Gopinatham disaster.

Numerous dams are now being built in the Himalayan mountains. As these are prone to landslides and seismic activity, the risk of dam bursts will grow. The proposed Tehri dam is facing much criticism because of the risk it runs of a collapse in case of a major earth tremor. Any resulting disaster would wipe out a population of over 75,000 people in the towns of Deoprayag, Hardwar and Rishikesh[11]. The landslides also increase the silt load of the Himalayan rivers, thus, affecting the storage capacity of downstream reservoirs.

The Indian experience, therefore, shows that dams are only a mixed blessing as far as flood control is concerned.

Major dam failures

Note : Map not to scale

The dangers

The committee outlined numerous dangers of constructing embankments. In areas where a river delta is extending rapidly, embankments would raise the flood levels and perpetuate the problem of drainage and waterlogging in adjoining areas. The committee recommended that proposals for constructing embankments for the third and subsequent plans should be studied in detail before they are accepted, though it did not go against embankments completely. It stated that, in general, embankments are satisfactory means of flood protection when properly designed, xecuted and maintained. But the most efficient way to build embankments, it argued, is to combine them with measures like dams.

After receiving this report, another statement was placed before Parliament in 1958 in which the government stated, "The various flood control measures either executed or visualised should not lead to a wrong impression that complete immunity from flood damage is physically possible in some distant future. *Any such illusion has to be dispelled* (emphasis ours Ed.). Even the best known methods of flood control aim only at providing what may be called a reasonable degree of protection. Complete protection even if technically feasible would not be economically justifiable in all areas and in all communities."

Thus, even before the 1950s were out, the idea of getting rid of floods was losing out while the idea of learning to live with floods was gaining ground. But the subsequent decades did little to expand on this theme. A ministerial committee on flood control was constituted in 1964 to assess the impact of the action taken since the 1954 policy statement. The committee pointed out that more attention should be paid to flood control methods other than embankments like minor storages, interbasin diversion of river waters, flood warning, flood forecasting, flood plain zoning, flood insurance and soil conservation. But it also felt that the biggest progress in the future would be made by integrating these measures with the construction of large multipurpose dams. Thus, by the 1960s, the emphasis had shifted to dams.

In 1972, another ministerial committee on flood and flood relief submitted its report reiterating the need for river diversion schemes, channel improvements, soil conservation programmes, flood plain zoning and prevention of encroachment upon drainage channels. But for the first time a high level government committee felt that all was not working well with even the modern technology of dams. It pointed out that flood moderation should be made an objective even in projects meant purely for power or irrigation. Where it is not possible to do so, at least water release schedules should be regulated to give maximum flood moderation downstream. Multipurpose dams have multiple objectives and often the objective of flood control when it clashes with the objective of generating power or providing irrigation, gets little importance.

In 1978, a working group on flood control was set up. This group reiterated the arguments made before. It, however, emphasised that flood affected states should

prepare master plans for each river basin. With respect to embankments, the group warned, "While embankments constructed so far have by and large given the desired protection to large areas at comparatively low costs, their consequent long term effects on river regime are yet to be evaluated. New embankment schemes should be taken up with caution." The group felt that dams should be built fast in flood prone basins and suggested that studies on proposed dams in Nepal should be carried out immediately.

The panel

In 1976, the government constituted a high level Rashtriya Barh Ayog (RBA). Its chairman pointed out that "the increase in flood incidence during recent years has been causing concern." The Ayog made a comprehensive evaluation of available flood control measures but failed to break any new path. It emphasised once again that comprehensive basinwise planning is necessary. Instead of stressing any one physical measure like a dam or an embankment an integrated set of measures should be implemented. And "in the absence of any viable measure," the commission stated, "one may have to live with floods." In such circumstances, flood plain zoning, which prevents undue occupation of flood plains, adjustment in cropping patterns, and raising of villages above flood levels would be the main measures available. The commission recommended that natural water detention basins like lakes and swamps should not be reclaimed for agriculture and be protected. Disaster preparedness should be strengthened through better flood warning systems.

The results

Despite this, flood control measures have rarely gone beyond the construction of dams and embankments. Between 1954 and 1978, 10,821 km long embankments had been built. By March 1987, this figure had gone up to 14,511 km (see table 8). Numerous rivers have had long stretches embanked on both banks. And despite all the warnings of the various committees, the rate of building over 400 km of embankments annually has been kept up since 1954. By the mid-1970s, a north Bihar river like Burhi Gandak had 317 km long embankments on its left bank and 312 km on its right bank; Kosi had a total length of embankments of 246 km; and, Bagmati some 333 km. By 1987, 4,448 km long embankments had been built in the Brahmaputra and Barak valleys of Assam. Some 459 towns and 4,701 villages had been protected across the country and 28,036 km of drainage channels constructed[2]. Overall, a total area of 13.37 mha had been protected as compared to 9.99 mha in 1978 and about three mha when the British left. Meanwhile, the total expenditure on flood control increased from Rs 13.2 crore in the First plan (1951-56) to Rs 786.8 crore in the Sixth plan (1980-85) and an outlay of Rs 947.4 crore in the Seventh plan (1985-90) (see table 9). Flood control outlays have generally fluctuated between 0.64 and 1.08 per cent of the total five year plan outlays[2].

In addition, the government has spent vast sums on constructing dams. By 1986, 256 large dams (with a height of 15 m and above) had been built and 154 more were under construction[10]. Only about 30-odd dams had been completed in the Indo-Gangetic and Brahmaputra valleys ∇ the most flood prone regions. Another 15-odd major dams were under construction in these areas.

Most of these dams are multipurpose dams. The results, as far as flood control is concerned have been mixed because of conflicting objectives. While flood control demands that the reservoir be kept as empty as possible to arrest any oncoming flood, irrigation and power generation demands that the reservoir be kept as full as possible. As a result, dams themselves have sometimes become major causes of floods (see box).

Table 8

Length of embankments

States	Length of embankments: From 1954 to 1978 (km)	Length of embankments: Up to March 1987 (km)	Area protected up to March 1987[1] (mha)
Andhra Pradesh	405	507	1.00
Assam	4145	4448	1.56
Bihar	2355	2756	1.87
Goa, Daman and Diu	7	9	-
Gujarat	208	408	0.43
Haryana	396	578	1.70
Himachal Pradesh	2	58	0.01
Jammu and Kashmir	-	56	0.06
Karnataka	-	-	Neg
Kerala	44	92	0.03
Madhya Pradesh	-	15	Neg
Maharashtra	26	26	Neg
Manipur	127	279	0.08
Meghalaya	45	106	0.09
Orissa	370	1007	0.46
Punjab	821	1047	2.66
Rajasthan	82	141	0.04
Sikkim	-	-	-
Tamil Nadu	-	35	0.08
Tripura	39	114	0.03
Uttar Pradesh	1174	1711	1.42
West Bengal	515	974	1.75
Delhi	60	83	0.08
Pondicherry	-	61	0.01
All India	10821[2]	14511	13.36

Note : [1] Area protected by all measures, including drainage channels and protection of towns and villages.

[2] An additional 6000 km of embankments had been built before 1954 (RBA).

Source : 2, 5

Table 9
Flood control expenditure

Plan period		Expenditure (Rs crore)	Cumulative area protected (mha)
First plan	(1954-56)	13.21	1.00
Second plan	(1956-61)	48.06	3.24
Third plan	(1961-66)	82.09	5.43
Annual plans	(1966-69)	41.96	5.83
Fourth plan	(1969-74)	162.04	8.04
Fifth plan	(1974-78)	298.60	9.98
Annual plans	(1978-80)	329.96	11.21
Sixth plan	(1980-85)	786.85	13.01
Seventh plan	(1985-90)		
	(1985-86)	166.30	13.18
	(1986-87)	186.77	13.35
	(1987-88)	181.55	13.48
	(1988-89) (anticipated)	211.99	NA
		2509.38	
Seventh plan outlay		947.39	14.10[1]

Note : [1] Target for 1989-90
Source : 2

Table 10
Statewise distribution of large dams on 31.12.1986

States	Number of dams	
	Completed	Under construction
Andhra Pradesh	24	18
Arunachal Pradesh	–	–
Assam	1	1
Bihar	9	1
Goa	–	4
Gujarat	51	35
Haryana	–	–
Himachal Pradesh	4	1
Jammu and Kashmir	–	1
Karnataka	13	14
Kerala	23	13
Madhya Pradesh	8	10
Maharashtra	50	33
Manipur	–	–
Meghalaya	3	–
Mizoram	–	–
Nagaland	–	–
Orissa	6	2
Punjab	–	1
Rajasthan	5	3
Sikkim	–	–
Tamil Nadu	51	9
Tripura	–	–
Uttar Pradesh	7	7
West Bengal	1	1
	256	154

Source : 10

Table 11
Number of large dams in India

Decade	Number of dams constructed
Before 1950	28
1950s (1950-59)	32
1960s (1960-69)	64
1970s (1970-79)	85
1980s (1980-86)	47
Under construction in 1986	154

Source : 10

THE ENVIRONMENTAL CONNECTION

During the 1980s, the popular perception that emerged was one of increasing floods despite all the investments made to block the flow of rivers during the first three decades of India's independence. Public criticism, heavily influenced by the growing concern for environment across the world, increasingly focused on the degradation of the watersheds of Indian rivers, especially on the extensive deforestation of the hilly and mountainous portions of their catchment areas. Deforestation came to be seen as a major cause of increased floods in the plains and afforestation was posed as a major solution to the problem.

British environmentalist, Norman Myers, for instance, argued this thesis very forcefully. In an article in the *Journal of World Forest Resource Management* he said, "In much of the Himalaya there is widespread deforestation in montane catchment areas, leading to environmental 'backlash effects' in the form of flooding and droughts, soil erosion, sedimentation and siltation, and a host of similar problems in the flood plains of the Ganga and the Brahmaputra among other major rivers. Primarily because of deforestation in their headwaters regions, the river systems are increasingly subject to disruption, leading to floods followed by droughts. All in all, these plains have been described as the 'greatest single ecological hazard on Earth.' Forest cover early in this century amounted to an estimated 60 per cent of land area, but it has now dwindled to only one quarter as much. In India, it is being reduced so rapidly that there may be little left by the end of the century. The Himalayan forests normally exert a *sponge effect,* soaking up abundant rainfall and storing it before releasing it in regular amounts over an extended period. When the forest is cleared, rivers turn muddy, and swollen during the main wet season, before shrinking during drier periods. An increasing proportion of rainfall is therefore released, shortly after precipitation, in the form of floods. Flood disasters are becoming more frequent and more severe. Siltation in the Ganga system is so pronounced that a number of river beds are rising at a rate between 15 cm and 30 cm per year, grossly aggravating floods. The situation in the Himalaya, already critical, appears likely to grow steadily worse. By

HIRAKUD'S TALE

The Hirakud dam in Orissa was one of the first multipurpose dams built after independence. Irrigation and electricity generation, however, were to be its secondary objectives because of the serious flood menace in the Mahanadi delta.

The recorded history of floods in the Mahanadi delta goes back to 1834. Before the Hirakud dam, the major form of flood control in the Mahanadi delta was embankments. Floods would damage large areas under crops and it was necessary to control floods for agricultural growth.

The Hirakud dam, commissioned in 1958, is the longest earthen dam in the world. Sadhana Satpathy of the Centre for Development Studies has studied its performance. Data on peak discharges in the Mahanadi over a period of 80 years up to about 1954 shows that a "normal flood" came once in three years, a "fairly heavy flood" once in five years, and an "abnormally heavy flood" once in 12 years. From this it was estimated that about 0.14 mha of cropped area was flooded on an average every year in the predam period. But postdam period data from 1958 to 1982 shows that the annual average crop area affected by floods is an estimated 0.216 mha. The dam has, therefore, been unable to reduce this.

Data on the frequency and intensity of floods in the predam and postdam periods, however, show otherwise. From 1931 to 1957 floods occurred in 78 per cent of the years as compared to 44 per cent from 1958 to 1984. The share of large and very large floods went down from 76 per cent to 42 per cent after the dam. The share of small and medium floods went up from 24 per cent to 58 per cent. The average intensity, declined from 33,220 cumecs to 30,250 cumecs. In other words, the dam has had a positive impact.

Why do the available figures give such conflicting results? Flood damages occur in the Mahanadi delta when the water level goes above 27 m at Naraj, the head of the delta. The maximum reserve required for controlling the severest flood has been estimated at 0.37 mham while the maximum live storage available in the Hirakud dam is 0.56 mham. The available data show that between 1958 and 1967, the peak discharge at Naraj was less than what it would have been in the absence of the dam except for 1962. The dam can, therefore, reduce all flood levels to less than 27 m at Naraj. So why were there any floods years, including three large and two very large flood years, in the postdam period ? Various factors inhibit Hirakud's role. To generate electricity, dam authorities fill the reservoir by August end. The dam's intake capacity is, thus, low in September leading to floods in case of late rainstorms. The 1980 floods which came in late September, for instance, were caused entirely by a forced release from the reservoir. The inflows into the reservoir have also increased since the predam period because of deforestation of the catchment. Siltation has led to a loss in the storage capacity of the dam. Between 1958 and 1981, there was a 1.27 per cent loss in dead storage, 0.48 per cent in live storage and 0.70 per cent loss in gross storage annually.

There is also evidence to suggest that in some cases the independent contribution of the catchment below Hirakud pushes the peak discharge to 25,500 cumecs or beyond at Naraj. Tributaries Ong and Tel join the Mahanadi below Hirakud. In 1964, there was no outflow from the Hirakud reservoir yet heavy rains in the downstream catchment in August kept the peak discharge at Naraj high. In 1982, for instance, when one of the worst floods recorded in the history of the Mahanadi delta took place, the peak discharge was 1.58 million cusecs. This flood was caused entirely by the runoff from the downstream catchment without any contribution from the Hirakud reservoir.

The dammed Mahanadi

Impact of Hirakud dam on floods

Floods	Predam period (1931-57)	Postdam period (1956-84)
A. 1. No flood years(%)	22	56
2. Small and medium flood years (%)	19	26
3. Large flood years (%)	26	11
4. Very large flood years (%)	33	7
B. 1. Average peak discharge (cumecs)	33,220	30,250
C. 1. Annual average Crop area affected by floods in the Mahanadi delta (mha)	0.17 (1955-57)	0.22 (1958-82)
D. 1. Short duration floods (0-1 days) (%)	64.5 (1920-50)	30.8 (1958-84)
2. Medium duration floods (2-3 days) (%)	22.6 (1920-50)	30.8 (1958-84)
3. Long duration floods (Over 3 days) (%)	12.9 (1920-50)	38.5 (1958-84)
4. Average duration of floods (days)	1.61 (1920-50)	3.17 (1958-84)

Note : [1]No flood year : Less than 25,500 cumecs peak discharge at Naraj, the head of the delta

Source : 1

Loss of Hirakud's storage capacity

Storage	Original capacity (1958) (mham)	New capacity (1981) (mham)	Loss per year (%)
Dead storage	0.23	0.15	1.27
Live storage	0.58	0.51	0.48
Gross storage	0.81	0.66	0.70

Source : 1

The downstream catchment has a crucial role to play in flood control. Since 1960 there has been significant deforestation in the catchment of the Mahanadi both above Hirakud and below which could be generating quick runoff in the postdam period. The contribution of the downstream catchment is probably the main cause of the low and medium floods in the postdam period with the situation worsening because of deforestation.

The available data also shows that the duration of a flood often has a greater impact on flood damages than its intensity. For instance, in 1964, the peak discharge at Naraj remained well below the danger level of 25,500 cumecs but because the water level remained between 25.9 m and 26.5 m for 15 days, severe damages occurred in the Mahanadi delta. On the other hand, in 1976, the peak discharge at Naraj was 26,430 cumecs but the damage was negligible because the flood lasted only for a day. Statistics show that the short duration floods have come down in the postdam period whereas the proportion of medium and long duration floods has increased. The average duration of floods has increased from 1.61 days in the predam period to 3.17 days in the postdam period. Sadhana Satpathy, therefore, concludes that the large and very large floods of a short duration in the predam period have been replaced by small and medium floods of a longer duration in the postdam period and, as a result, there has been no decline in crop area affected.

How could this have happened ? The embankment system is pretty extensive in the Mahanadi delta. Even as early as 1872, nearly 50 per cent of the total length of the delta channels in the Mahanadi basin had embankments. By 1940, 80 per cent of the area liable to flood had been protected. Most of these embankments came up in an unplanned manner. Over the years, the silting of the river beds has probably increased the flood levels. Breaches in the embankments are common, especially because of their poor maintenance. Human occupation of the flood plains has also increased. It is probably because of these factors that flood damages have not decreased despite a fall in the average intensity of floods in the postdam period.

Thus, Sadhana Satpathy's study shows that dams by themselves cannot reduce flood damages unless measures are taken at various points across a river's basin. She concludes, " The limited effectiveness of large dams in flood control is due to a complex set of changing conditions, all of which cannot be attributed to large dams. A critique of the present direction and thrust of flood control policies is warranted but such a critique should go beyond a simple (fundamentalist) denunciation of all that is large and advocacy of all that is small."

way of response there is need for three separate sets of measures, plant trees, for both fuelwood and fodder on denuded slopes; plant bulky forage grasses in eroded gullies and along drainage lines; and, permit livestock to graze only when they are tethered, and near to terraces"[11].

This perspective is now widely shared by a range of people, from technocrats and bureaucrats to well meaning politicians, social workers and aid givers. An Oxfam report on floods in India, for instance, points out "Floods are now an annual feature, and there are many flash floods. The problem in the main is due to reduced and inadequate capacity of the river channels due to silting caused by devastation of forests in the catchment areas which leads to heavy soil erosion and heavy runoff."

An extreme statement based on the same perception is one from a World Bank and UNDP sponsored study entitled *Tropical Forests: A call for action*, prepared by the World Resources Institute (WRI), which pits the poor in the Himalayan mountains against the people living in the plains[12]. The document states, "The Himalayan range contains the world's most severe watershed problems. *On the lowland plains of Pakistan, India and Bangladesh, over 400 million people are 'hostage' to the land use practices of 46 million hill dwellers* (emphasis ours Ed). In India alone, the costs of increasing flood damage and destruction of reservoirs and irrigation systems by sediment from *misused slopes* have averaged US $ 1 billion a year since 1978."

The WRI report, therefore, puts the blame for environmental destruction squarely on the poor hill dwellers and looks upon the plains dwellers as the victims of their misdeeds.

The sponge theory inherent in the environmentalists' argument has come to be shared by numerous Indian environmentalists and research institutes. The Forest

FLOOD RAVAGED: A family contemplates its bleak future with floods having washed away a portion of their house. (N Thiagarajan / Hindustan Times)

EERIE ISOLATION: Silence descends upon an abandoned and marooned village in north Bihar as floods convert lush farmlands into a vast ghostly expanse of water. (Krishna Murari Kishan)

Research Institute (FRI) in Dehra Dun, for instance, has even presented detailed calculations to make its case. It argues that the forest areas of India receive twice the rainfall of non-forest areas. Therefore, nearly 40 per cent of the country's water resources come from forest areas, which cover about 20 per cent of India's land area. The soil moisture storage capacity of India's 328 mha land area has been estimated at 224 mham or 0.68 m on average for all soils. Therefore, the 70-odd mha of India's forest lands can store as much as 50 mham of water. Assuming 50 per cent of this water will be retained in the top layers of the soil as soil moisture, the forested areas can store 25 mham. The FRI argues that this storage will prevent floods during the monsoon months and then as water is released slowly from the soil to augment lean season flows, it will help to combat drought situations.

According to the FRI, an estimated Rs 1,25,000 crore will be needed to construct dams to store the same quantity of water. Therefore, afforestation can reduce floods more cheaply than dams. Geologist K S Valdiya of Kumaon university warns that even big Himalayan rivers will not contain anything other than snow melt during the dry season if deforestation continues as it is today[14].

Even Indian prime ministers have shared this viewpoint. Former Prime Minister Rajiv Gandhi, for instance, said in a note to the Centre for Science and Environment in 1986, "I have started a debate in our parliamentary party on floods and droughts during the past two years and how environmental degradation is affecting them. The logic I have sold them is that with environmental degradation even low rainfall becomes a (flash) flood and the water rushes into the sea (taking the top soil) and then is not available as groundwater, thus, a vicious circle"[15].

FLASH FLOODS

The flood prone Vamsadhara which broke all its bounds in September 1980, forms a drainage basin covering parts of Andhra Pradesh and Orissa. The 230 km long Vamsadhara has a catchment of 1.06 mha and rises in the Pulbhani district of Orissa. It drains part of the Kalahandi, Pulbhani, Ganjam and Koraput districts in Orissa and Srikakulam district in Andhra Pradesh and finally flows into the sea at Kalingapatnam. Floods in Vamsadhara are mainly due to rainstorms arising over the Bay of Bengal. On most occasions, they are welcomed since the water gets diverted for irrigation purposes by the Gotta barrage. The 1980 flood, however, defied all calculations as the river flows reached unprecedented levels. J M Girglani, then collector of Srikakulam district, claims that it was like river Krishna flowing through the Vamsadhara[1,2].

The September 1980 flash floods were produced by a deep depression formed over the Bay of Bengal. Water flows are generally high during September. But in 1980 they received additional rainfall over a short period making the water volumes very high. The short period between the intense rainfall and flooding precluded advance warning. Flood waters reached the affected areas in quick succeeding waves. Near the mouth of the river, villages were under a sheet of 4.5 m of water. Over 300 villages inhabited by over 0.2 million people living across a spread of 54,540 ha were affected[1].

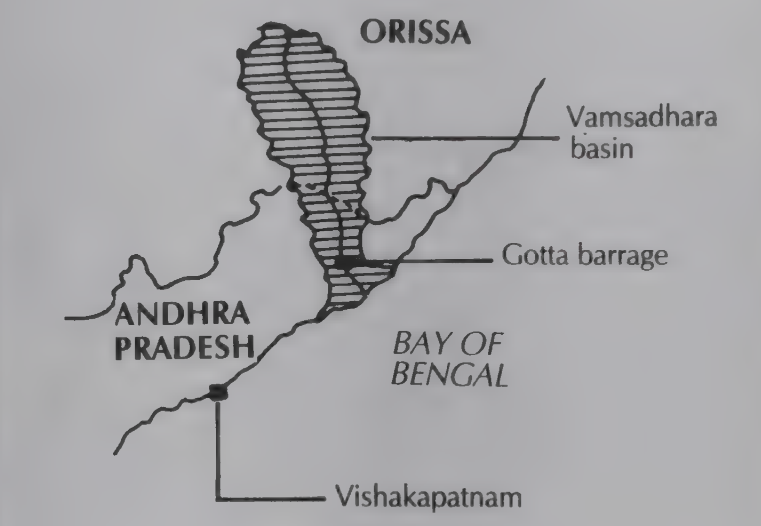
E Amminedu of Andhra university, who has studied the 1980 flood for his doctorate, observes that all known floods in 1938, 1972, 1977 and 1980 took an almost identical route varying only in quantum of discharge and height of water level. Heavy discharges in the river led to overflows along the river banks because of the shallowness of its bed. The damage costs in 1980 were of the order of Rs 130 crore.

Amminedu found something puzzling regarding the 1980 flood. The river's peak discharge at Kashinagar was 13,000 cumecs ∇ nearly double the previous maximum discharge of 6,590 cumecs during 10 years of recorded flood history. The peak discharge at Gotta barrage on September 17th was again 11,400 cumecs as compared to the earlier high of 6,800 cumecs. But when Amminedu compared the monsoon rainfall levels of 1980 with that of 1972, an earlier flood which had a relatively low discharge, he found that several subbasins of the Vamsadhara, especially those situated in the north, had recorded more or less same rainfall levels. The average depth of rainfall over the entire basin in 1980 (1,420 mm) was only nine per cent over the normal. Yet it was the subbasin lying in the north which had contributed more flood water into the main river course.

Amminedu argues that one reason was the intense rainfall. The basin received more than half the rainfall it normally receives in September in just 24 hours. He also claims that factors such as sedimentation and changes in land use also contributed to the occurrence of the 1980 flood. Firstly, when satellite imagery of 1973 was compared with aerial photography of 1977-79, there was evidence of substantial deforestation and vegetative degradation. Secondly, toposheets of 1933-1934 when compared with those of 1973-74 revealed that bank heights at various places south of Gotta barrage had decreased by 0.6 m to 6.7 m. This had greatly reduced the carrying capacity of the river (see table).

Amminedu's thesis is one of the first detailed studies in India to show a link between deforestation and an actual flood. Unfortunately, it fails to give an idea of the relative importance of meteorological and environmental factors in the causation of that flood.

The Vamsadhara basin



The Vamsadhara witnessed a disastrous flood in September 1980. Studies show that environmental factors were responsible to some extent.

Reduction in river bank heights in Vamsadhara basin

Location	Bank height 1933-34 (m)	Bank height 1973-74 (m)	Bank height Difference (m)
Modukuvalasa	4.57	3.96	- 0.61
Mukhalingam	5.18	3.05	- 2.13
Batteru	4.57	3.05	- 1.52
Buchipeta	4.57	3.05	- 1.52
Aravapeta	9.75	3.05	- 6.70
Suggadaluvanipet	3.66	2.13	- 1.53

Source: 2

BREACHED DEFENCE: When floods occur people are forced to take shelter upon any available space, whether it is an embankment or a road. (Bhawan Singh/India Today)

THE WRATH OF NATURE: The railway bridge near the Nala Power House in Jaipur attracts the full fury of the flood waters in 1981. While the railway line remains intact, the bridge is washed away. (India Today)

However, India's water resources establishment has not accepted the environmental perspective. The flood control engineers of the ministry of water resources, for instance, have continued to argue that the ecological solutions being proposed will not make much difference. They have continuously stressed engineering solutions over ecological ones. They want more of the same solutions applied over the first three decades. This has led to tremendous suspicion and distrust between water resource engineers and environmentalists, and to an endless debate.

While environmentalists have complained that water resource engineers are close minded and obdurate and allegedly even dishonest, more interested in the financial opportunities that megaprojects offer, water resource engineers have argued that environmentalists are more emotional than scientific. Meanwhile, as far as the nation is concerned, the flood problem continues unabated.

This publication tries to explore the available evidence on the effects of environmental degradation in the Himalaya on floods in the sub-Himalayan plains. Of the five most flood prone states, Uttar Pradesh, Bihar, West Bengal, Assam and Orissa, four lie in valleys of the two major Himalayan rivers, Ganga and Brahmaputra. The publication also presents information on the historical and latest perceptions of the flood problem in the north Bihar plain and the Assam valley.

- *The deep gorges of Himalayan rivers seem sufficient to transport excess rainwater. Surprisingly, this is not true. Floods have been taking place in the Himalayan mountains since time immemorial.*

- *Landslides often block Himalayan rivers. When these landslide dams burst they cause a flood pulse which triggers off more landslides.*

- *In 1893 a landslide blocked the Birahiganga in the Uttar Pradesh Himalaya to form a 350 m high dam creating the vast Gohana Tal. When a part of the dam toppled 10 months later, the level of the Alaknanda rose by 50 m and washed away the town of Srinagar.*

- *During a normal year, some 0.5 mm to 5 mm of soil depth gets washed away in the Darjeeling Himalaya. During a year of catastrophic floods, such as in 1968, some 20 mm deep soil can get eroded. Hardly any mountain range in the world experiences such high erosion rates.*

- *Cyclonic storms in Darjeeling and Sikkim can bring 310 mm to 1,800 mm of rainfall in a day. Cloudbursts exceeding 1,000 mm in a day can trigger massive landslides in practically any geological circumstance.*

- *The Teesta flowing through the Sikkim and Darjeeling mountains is possibly the wildest river in the Himalaya. After the destructive floods of 1787, the Teesta, which used to flow into the Ganga, changed course and started flowing into the Brahmaputra.*

CHAPTER 2

Havoc in the Himalaya

The Himalayan mountains constitute an ecological system naturally primed for disaster. The deep gorges through which the Himalayan rivers flow convey the impression that the Himalayan valleys would never face floods. Yet these very channels often fail to contain the fury of disastrous floods. Among the most affected valleys are the Alaknanda and Bhagirathi valleys of the Garhwal Himalaya and the Teesta valley of the eastern Himalaya.

The Himalaya, the youngest mountain range in the world, is one of the most erosion prone ranges. The brutal rainstorms which lash these mountains, together with some of the world's worst earthquakes give the Himalaya an ecological setting extremely susceptible to natural disasters and floods.

FLOODS IN GARHWAL

Both the Bhagirathi and the Alaknanda — the two major central Himalayan rivers which join to form the Ganga — have faced major floods. Both emerge from the snow clad Chaukhamba range which consists of enormous glaciers and snow fields. Bhagirathi rises at Gangotri on the northwestern face of Chaukhamba, whereas Alaknanda emerges from the Satopanth glacier at Alkapuri on the southeastern side of the range, a few kilometres above the famous Hindu temple town of Badrinath[20].

An analysis of rainfall data in the Garhwal-Kumaon Himalaya shows that the average annual rainfall at different sites is about 1,000 mm to 2,500 mm of which 50 per cent to 80 per cent comes down during the monsoon, occasionally very heavy rains can be expected. Once every 100 years, 200 mm to 500 mm of rain can be expected in one day. The "probable maximum precipitation" in a day is estimated to be 500 mm to 700 mm. In September 1880, a rainstorm recorded 820 mm in one day and 1,040 mm over two days at its centre in Bijnor district. This is considered to be one of the severest of the world for a two day duration. Similarly, in September 1924, 770 mm of rainfall took place over three days.

There are two zones of maximum rainfall in the central Himalaya — one near the foot of the mountains and another at an elevation between 2,000 m to 2,400 m. At elevations beyond 2,400 m, rainfall decreases sharply[21]. Rainfall is scanty above 3,500 m although occasional cloudbursts take place.

Till they enter the lesser Himalaya, Bhagirathi and Alaknanda pass through very deep gorges, with steep gradients and sharp bends and meet even steeper tributaries. The westward flowing tributaries which meet the Alaknanda's left bank have the steepest gradients (see table 12). Both valleys are highly prone to landslides, especially when they face high intensity rainstorms.

The natural absence of vegetation in the higher reaches of the catchment areas, where the ground is made up of unconsolidated moraine, greatly helps in the formation of landslides. The downpour from cloudbursts digs into the soft ground. Moreover, the rivers in spate wash away the toes of the slopes and wherever the rivers take a sinuous course, bank erosion is extensive[20].

The resulting landslides block the rivers and when the

Table 12

Average channel gradients of Himalayan rivers in the Ganga watershed

River/Tributary	Mean channel gradient (m/km)
ALAKNANDA	48
Dhauliganga	75
Nandakini	67
Mandakini	66
BHAGIRATHI	42
Bhilangana	52

Source : 20

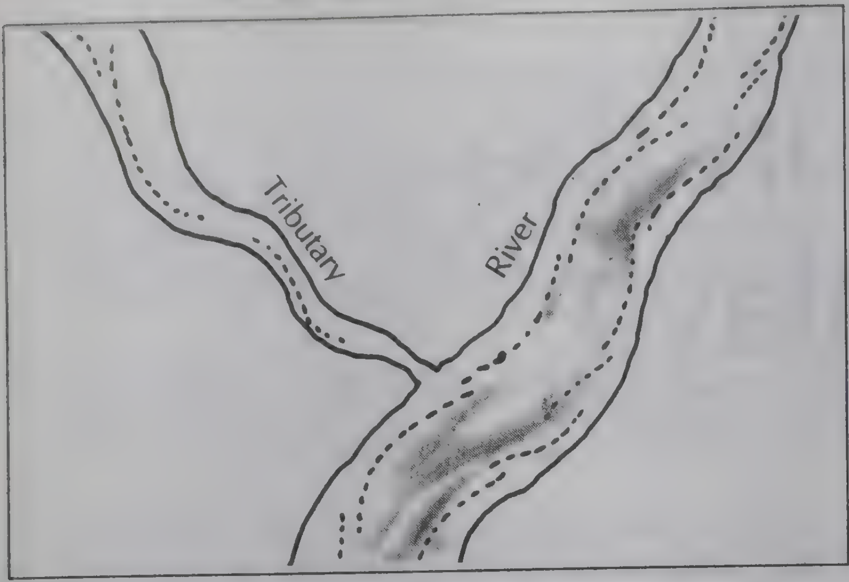
Table 13

Altitudinal zones of the Ganga watershed in Garhwal

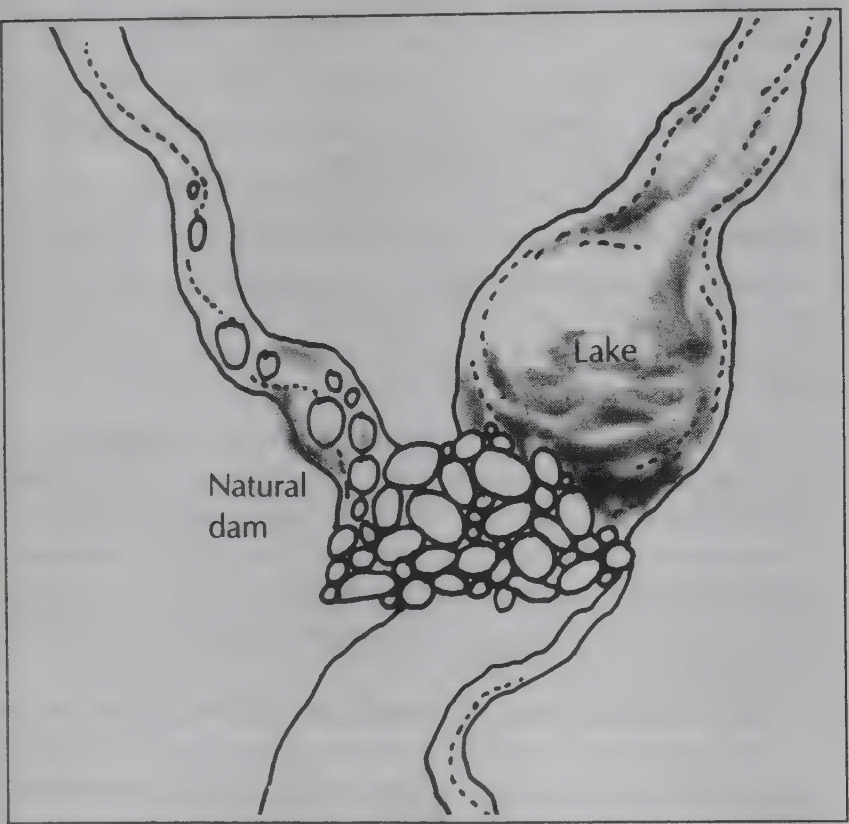
Altitudinal zone	% of total area
Less than 1200 m	11
1200 to 2000 m	24.1
2000 to 2400 m	9.5
2400 to 3600 m	16.6
Above 3600 m	38.8
Total Area (mha)	2.14

Source : 43

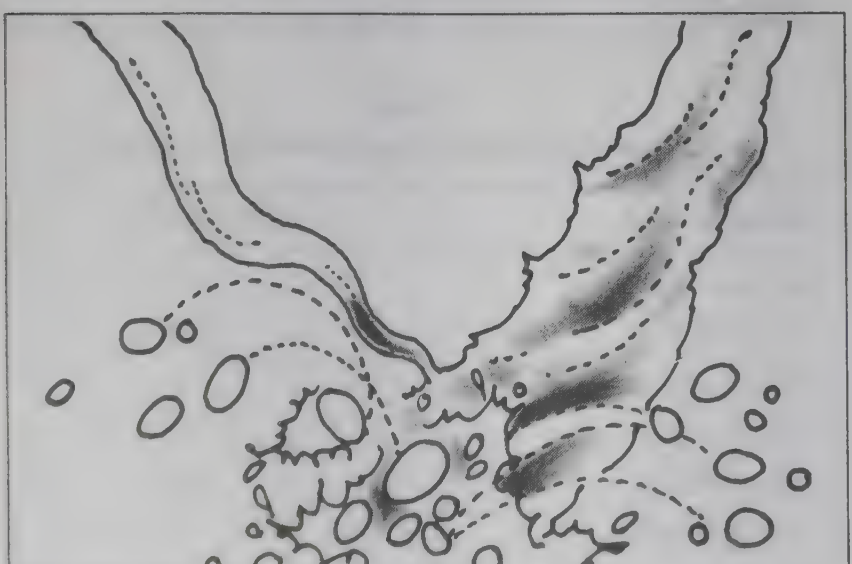
Natural dams in the Himalaya



Landslide dams usually get formed on major Himalayan rivers at their confluence points with steep tributaries.



During a heavy downpour, even minor tributaries can bring enormous amounts of rubble to block the flow of major rivers. A huge lake usually gets formed behind the dam.



The landslide dam finally bursts to send a flood pulse down the river.

landslide dams burst, they cause a flood pulse down the valley triggering off further landslides. Floods in Himalayan valleys are often associated with this phenomenon. The movement of landslide material in tributary streams, choking of channels and formation of temporary reservoirs is a continuous process in different parts of the catchment of the central Himalayan rivers. The tributary streams often bring down enormous quantities of landslide materials into the main rivers and block their channels [20]. Reckless road building and extensive deforestation during the 1960s and 1970s have further added to the inherent instability of the region[14]. The area has suffered massive deforestation since the last century.

Floods in the Alaknanda

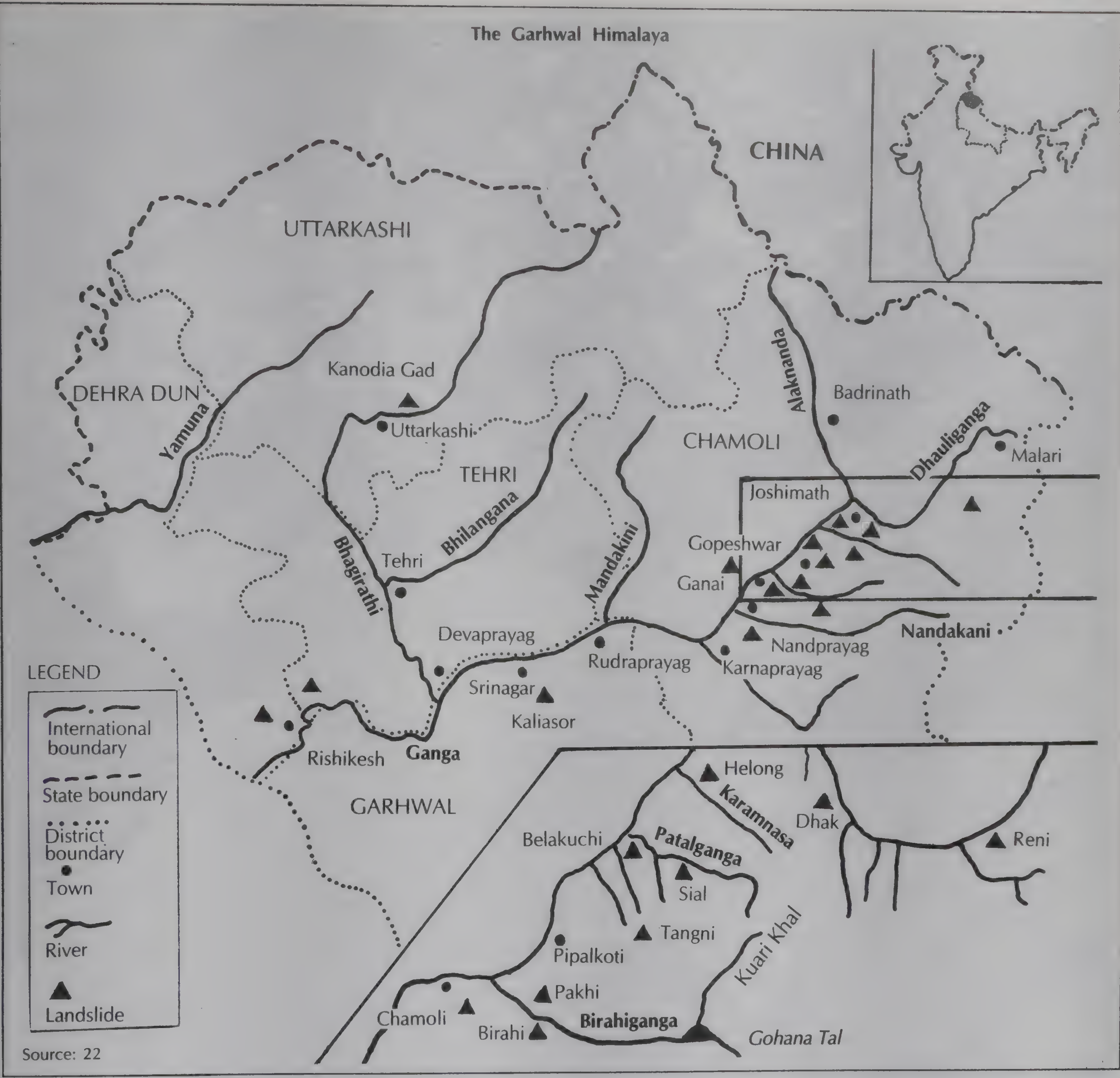
The Alaknanda drains a large catchment. The first major stream it meets is the Dhauliganga, which comes down from the Niti pass on the Tibet border. The first stretch of the Alaknanda from Alkapuri to Vishnuprayag, where it meets the Dhauli, is often called the Vishnuganga. Further down, the river meets several medium and minor tributaries on its left bank, namely, Patalganga, Karamnasa *Nadi* and Birahiganga. At Nandprayag, it meets the Nandakini, and at Karnaprayag, the Pindar, which drains the western slopes of the Trishul.

The Mandakini, which rises in the Chaukhamba range meets the Alaknanda on its right bank at Rudraprayag. Finally, the Alaknanda meets the Bhagirathi at Devprayag and becomes known, thereafter, as the Ganga. Numerous landslides can be seen along the river and its tributaries. The first major landslide, as one climbs up the valley, is the Kaliasor landslide located around the 147 km post of the Hardwar-Badrinath road. It is situated on a sharp bend on the left bank in the Alaknanda.

In September 1969, a huge landslide took place, some three km upstream of the small market place of Kaliasor and blocked nearly three-fourths of the width of the river. The hillside is reported to have kept slipping for four days. There was heavy rainfall during the week preceding the landslide with a flood in the river the day it occurred. Since 1969, the slide has become a menace for traffic. Rocks and mud now regularly move down the Kaliasor slope and massive efforts have to be made during the monsoon to keep the road clear.

There were three major causes of the slides. First, there was extensive toe cutting by the river at the point of the bend in its course. A topographic map of 1920 shows a cliff jutting into the river but its size had already been reduced to nearly half prior to the slip. Second, the overlying rocks and soil failed because the slope itself is very unstable due to the closely jointed and highly sheared rock mass. The third factor was the heavy rain preceding the slide.

Further up the Alaknanda, the valleys of Nandakini, Birahiganga, Garurganga, Sialgad, Belakuchi Nala, Helang Nala, Karamnasa Nadi and Dhauliganga bristle with landslides. Some of these landslides are very old but they have been reactivated in recent years because of their toes being washed away by the rivers. The Reni slide on the Dhauliganga basin formed a 40 m high landslide dam on



Source: 22

the Girthiganga in 1968. The hill slopes at Badrinath, near the source of the river Alaknanda, have witnessed numerous avalanches which have damaged houses in Badrinath in 1948, 1952 and 1975[22]. Rock falls are also not uncommon. In September 1968, a huge rock fell on a bus full of pilgrims a few km before Joshimath. The passengers were killed instantaneously[23].

In several villages of the Alaknanda valley, landslides affect an average of one ha to 1.5 ha of agricultural and forest land. And near villages like Chamoli, Pipalkoti, Maithana, Pakhi and Helang, seven to 10 landslides can be found per 100 ha of land[24]. The Border Roads Organisation (BRO), which constructs and maintains major roads in the Himalaya, has to repeatedly face problems caused by landslides. Engineer E V Narayanan of BRO claims that the Himalayan mountains constitute "one of the most difficult terrains in the world" to maintain roads.

Along the Joshimath-Malari road, Dhauliganga meets the Girthiganga (also known as Rishiganga) near Reni village. Some 250 m downstream of the bridge, across Girthiganga a landslide blocked the river in February 1968. The rainwater that had crept into the crevices froze because of the low temperature. This expansion in its volume not only shattered the rocky hillside, but the ice also acted as a lubricant for the sliding rocks and mud. As a result a huge lake was formed above the slide and the bridge on the Girthiganga was submerged.

According to Narayanan, BRO's staff had to work round the clock braving snow and blizzards to restore the bridge because of the importance of the road[23]. There are 90 major

SILT LOAD: This picture taken at the confluence of the Alaknanda and Bhagirathi, three months after the 1970 flood, shows the Alaknanda still bringing down an enormous amount of silt as compared to the Bhagirathi. (Virendra Kumar)

and minor landslides on the Rishikesh-Badrinath and Joshimath-Malari roads that regularly give trouble to the BRO[25].

Historical records reveal numerous landslide generated floods in the Alaknanda valley. Edwin Atkinson says in his *Himalayan Gazetteer,* first published in 1882, that Srinagar — then the only place in the Garhwal district approaching a town — had to face floods several times. A palace had been built by the Garhwal *rajas* long before the British but a huge flood (exact date unknown) swept away one-third of the town. By 1803, the rajas ceased to live in Srinagar and the town was in ruins.

Again, in 1868 and 1880, the town suffered greatly because of sudden floods. In 1868, a landslide dam burst and caused much damage along the valley. Two bridges were swept away and some 70 pilgrims sleeping on the river bank near Chamoli, nearly six metres above the ordinary flood level, were killed[26].

In 1893, a landslide — the largest known in the central Himalaya — blocked the Birahiganga to form a colossal 350 metre high dam. The lake behind the dam, now known as Gohana *Tal*, was five km long and two km wide. Ten months later, a part of the landslide dam toppled. The sudden surge of water sent a tidal wave down the valley raising the level of the Alaknanda by 50 m at Srinagar, some 100 km away, and the entire town was washed away. Hours later, when the wave reached Hardwar, another 100 km away, the Ganga's level rose by nearly four metres[27].

1970 flood

The worst flood in recent history in the Alaknanda valley took place in 1970. On the night of July 20, a cloudburst took place on the Kuari Khal mountain divide at an altitude of 3,700 m. It had been raining for days but finally some 275 mm of rainfall took place within a few hours that night. All streams emerging from the mountain divide — Rishiganga and Dhak Nala which drain into the Dhauliganga and Patalganga, Karamnasa Nadi, Helang Nala, Garurganga and Birahiganga which drain into the left bank of the Alaknanda — went into spate. The streams joining the Alaknanda on its right bank, however, were not affected while the damage in the catchment on the left bank was extensive.

A study carried out by the Indian National Science Academy, immediately after the 1970 floods, found that the heavy rainfall on the night of July 20 had triggered off numerous landslides. The slopes already saturated by prolonged rains failed under the impact of the final cloudburst. These landslides blocked numerous streams and when the landslide dams burst, a turbulent jet of turbid and debris charged water violently shifted course in the valley and caused severe toe erosion. This created further instability in the hanging slopes and induced huge landslides. The river is reported to have risen by 30 m to 60 m above the normal level at certain places[28].

The 1968 landslide dam on the Rishiganga near Reni village was toppled. The Dhak Nala deeply scoured its narrow bed and the resulting toe cutting reactivated the prehistoric Kuari pass landslide. A 300 m stretch of the

Table 14

Land use in the Ganga watershed in Garhwal

Land use	Bhagirathi watershed		Alaknanda watershed		Direct Ganga watershed		Total Ganga watershed	
	Area (mha)	(%)	Area (mha)	(%)	Area (mha)	(%)	Area (mha)	(%)
Cultivated Land	0.12	16	0.15	13	0.08	33	0.35	17
Forest Land	0.24	32	0.39	34	0.12	50	0.75	35
Blanks	0.13	17	0.13	11	0.04	17	0.30	14
Snow	0.26	35	0.42	37	–	–	0.68	31
Rocky Area	–	–	0.06	5	–	–	0.06	3
Total Land	0.75	100	1.15	100	0.24	100	2.14	100

Source : 43

Table 15

Status of erosion in the Ganga watershed in Garhwal (by type of land use)

Land use	Status of Erosion				
	Area (mha)	E 1 (%)	E 2 (%)	E 3 (%)	E 4 (%)
Cultivated land	0.35	13	74	13	Neg
Forest land	0.75	33	40	27	Neg
Blanks	0.30	9	12	71	8
Snow	0.67	-	-	-	-
Rocky Areas	0.06	-	-	-	-
Total	2.13	15	28	22	1

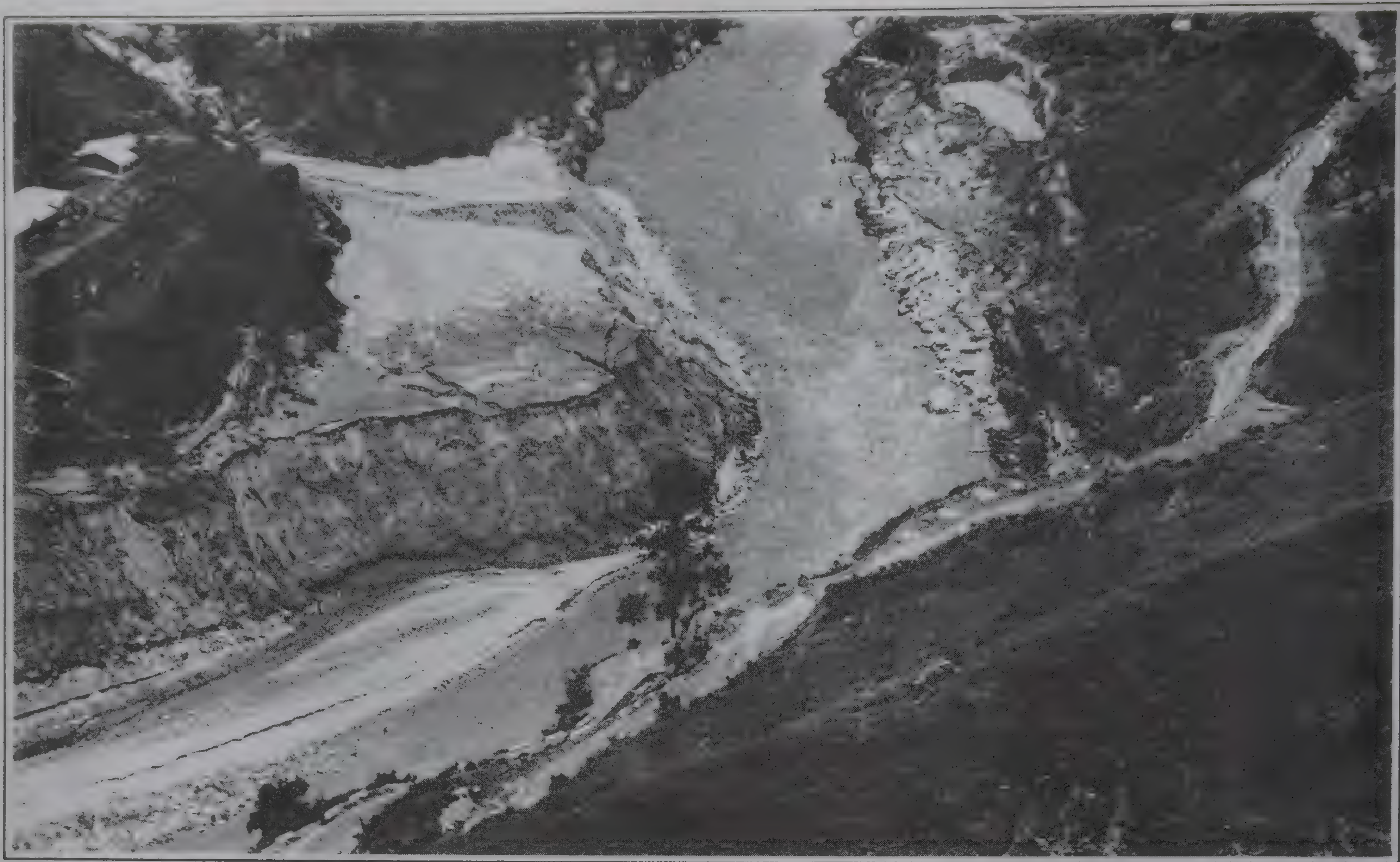
Table 16

Status of erosion in the Ganga watershed in Garhwal (by sub watershed)

Watershed	Status of erosion				
	Area (mha)	E 1 (%)	E 2 (%)	E 3 (%)	E 4 (%)
Bhagirathi watershed	0.74	12	27	27	Neg
Alaknanda watershed	1.15	16	25	16	2
Direct Ganga watershed	0.24	21	45	33	1
Total Ganga watershed	2.13	15	28	21	1

Notes : E 1 : Area in good condition.
E 2 : Area under satisfactory condition but needs treatment.
E 3 : Area susceptible to erosion and contributes the maximum silt load.
E 4 : Area completely destroyed and treatment is extremely difficult.

Source : 43



BLOCKED FLOW: The flow of the Alaknanda partially blocked by the rubble brought down by a petty tributary during the 1970 flood. (CBRI)

END OF THE ROAD: The Alaknanda washed away the road to Belakuchi in 1970. (PIB)

Joshimath-Malari road near the Dhak Nala slumped by 40 m and the landslide debris temporarily blocked the Dhauliganga with a 15 m to 20 m high dam.

The flow in the Karamnasa Nadi reactivated another prehistoric slide which carried away a part of the road and blocked Alaknanda even as inhabitants of several villages in the vicinity of the Helang nala prayed for their lives throughout the night.

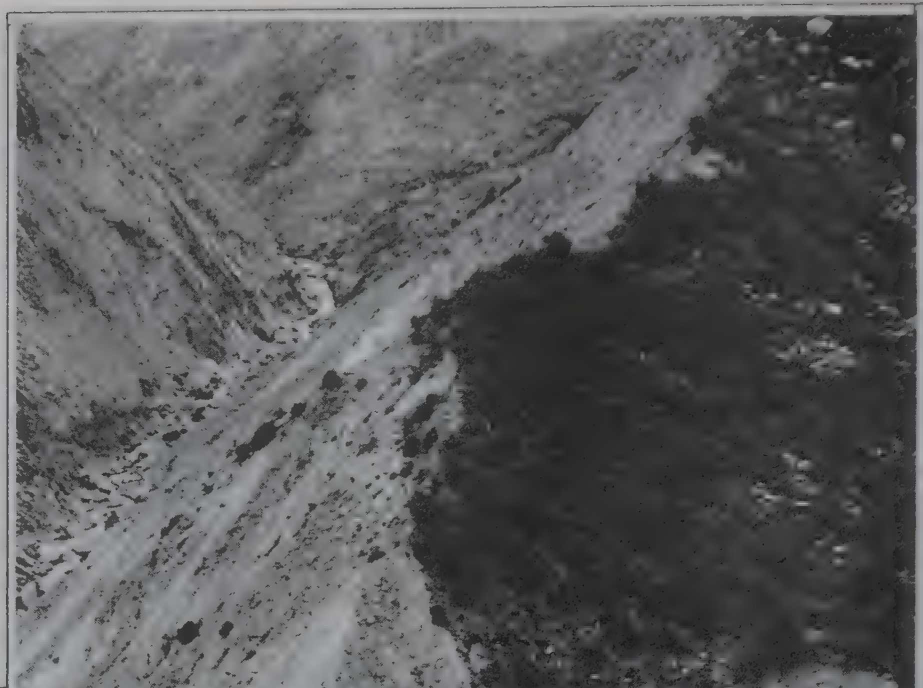
The Patalganga catchment was extensively ravaged and huge boulders were dislodged from the bare, deforested slopes. Most of the boulders came from Sankora Nadi, a minor tributary. The silt and boulders which came down the Patalganga formed a dam at its confluence with the Alaknanda. When this burst, the debris created another on the Alaknanda where the gorge is very narrow. This made the water in the already swollen river rise rapidly.

Just below the dam, at Belakuchi village, a police constable noticing that the river had no water sensed danger and immediately warned the people to run up the hill, this included about 400 pilgrims *en route* to Badrinath waiting at Belakuchi. The people were saved but the caravan of 30 odd buses, trucks and taxis was swept away by the dam burst. The old Belakuchi landslide was reactivated and as the hillside slid down into the river, the village and the bridge of Belakuchi were both swept away.

Further down, the flood pulse from Belakuchi met a flood pulse from Birahiganga. The Gohana Tal on the Birahiganga was still nearly 200 m deep, even after the landslide dam which had made the lake, had been partially washed away in 1894. The outlet was choked by rocks and trees and when it gave way, a high flood washed away everything in its path[29]. The swollen Birahiganga rose by 10 m to 12 m and washed away numerous bridges, culverts and roads[22]. The Gohana Tal received so much silt that night that it silted up. Fortunately, for the people of the valley, the lake did not burst. But the two flood pulses of Birahiganga and Alaknanda together eroded both sides of their banks almost right up to Devprayag[29].

The 1970 flood brought an estimated 9.1 mcum of silt and rock into the Alaknanda, eroded largely from the catchment of two petty streams, Patalganga and Garurganga[14]. The Alaknanda turned gray for weeks and parts of Srinagar found themselves buried under several feet of silt. Deposits of sediments could be seen for years up to 50 m above the level of the Alaknanda [30]. The silt was carried as far as 200 km downstream to Hardwar, where the Upper Ganga Canal, the irrigation lifeline of western Uttar Pradesh, was choked with stones, silt and mud for a stretch of 10 km.

PARALYSED TRANSPORT: The Alaknanda brought down such large quantities of silt in 1970 that a bus found itself stuck in the silt left behind at Srinagar. (N Thiagarajan/Hindustan Times)



DAVID AND GOLIATH: In August 1978 the Kanodia Gad a petty stream brought enormous debris into the Bhagirathi and blocked it for days with a 175 m wide wall — possibly the largest landslide known this century in the Ganga valley. The Kanodia Gad, the narrow stream on the left, can still be seen choked with rubble when this picture was taken nine years later in 1987.(Amar Talwar/CSE).

HUNG UP: Flood waters of the Alaknanda cut deep into the rocky mountainside leaving an army border post hanging in mid air.(PIB)

The canal had to be closed down for a desilting operation that cost several crores of rupees[29].

For the people of the Alaknanda valley, the night of July 20, was a nightmare. Nobody living along the river then thought they would see the next dawn. As landslide dams broke, huge boulders were thrown far and wide. The roar from the deep gorge was not only deafening, but the sparks which rose when the huge boulders collided hitting each other made local people claim that the river was on fire that night. There was one fortunate result of this entire tragedy, however. The ecological consciousness that resulted from this flood gave birth, three years later, to the now world famous *Chipko* movement to protect and conserve forests.

Floods in the Bhagirathi

In 1978, a major flood took place in the Bhagirathi valley. This time a petty stream called the Kanodia Gad brought enormous debris into the Bhagirathi and blocked it for days. This landslide is one of the biggest to have taken place in this century in the central Himalaya. It is 3.75 km long and 1.4 km wide and it has blocked the Bhagirathi by a 175 m wide wall.

The origin of the Kanodia Gad lies in the pastures of the 13,000 m high Mulyata Danda mountain. To the northeast of the Kanodia Gad is the rocky area of Gairaridhar, which is made of glacier moraine. Some 50-80 per cent of the area was covered by oak forests. The local shepherds would take their animals to this area for grazing from May to June. According to them, the area had many cracks, fissures and small slides. In the southern part of Kanodia Gad, there were heavily forested areas. The catchment therefore was geologically unstable but reasonably well covered by forests.

The shepherds claimed that the 1978 slide began soon after midnight on August 6. It was a massive slide — like a river of flowing mud — about 400 ha forests were destroyed as trees snapped like toothpicks. The slide spread all the way to Bhagirathi and blocked its flow for 14 hours forming a lake 35 m high, 45 m wide and about 3 km long. The dammed Bhagirathi then began to flow over bridges that were usually tens of metres above the river level. The slide was partially breached at 1900 hours on August 10 and again on 0100 hours on August 11. Each time a flood pulse went down the valley. The second breach led to massive floods and destruction. The town of Uttarkashi had a narrow escape. An abutment in the river swung the flood water to the river bank on the other side of Uttarkashi.

The area around Gairaridhar became so unstable that

SHED BURDEN: For years the phenomenal amount of silt brought down by the 1970 flood could be seen deposited above the Alaknanda river. The centre of the picture also shows a washed away bridge. (Virendra Kumar)

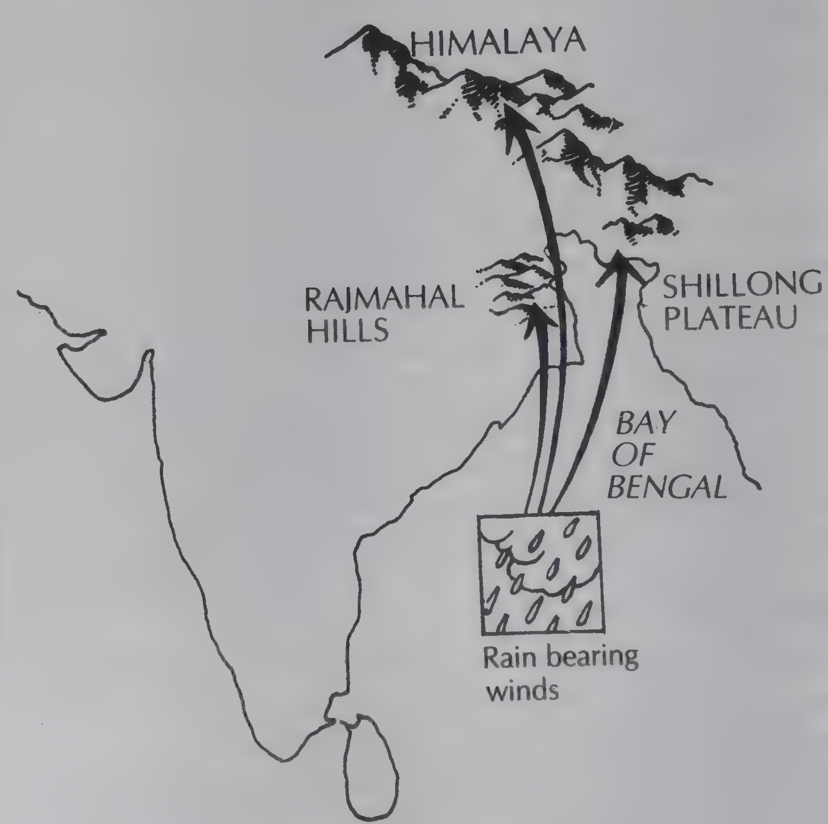
minor slides kept taking place for several days. Even after August 11, the Kanodia Gad would get occasionally blocked by falling rubble, and when these blockages would clear, the waters of Kanodia Gad would come rushing down with fury leading to a minor flood pulse. For days, the people in the Bhagirathi valley trembled with fear[31]. Fortunately, the entire landslide was never breached and even today constricts the Bhagirathi's passage.

FLOODS IN TEESTA

The Teesta, flowing through the Sikkim and Darjeeling hills, is possibly the wildest river in the Himalaya with a valley extremely prone to cloudbursts, landslides and flash floods. Deep and dense gullies and streams, rapid toe erosion,loose, jointed and fractured rocks, and extremely high intensity bursts of rainfall are characteristics of the area. The landscape of the valley is being continuously reworked by natural forces and most present day slopes have been formed by earlier landslides[32].

The Teesta has the highest sediment yield of all the Himalayan rivers bringing down approximately 98 cum of silt per hectare of its catchment per year[14]. This gives an annual denudation rate of 9.8 mm per year, which is amongst the highest denudation rates estimated for any river valley in the world. A scientist has estimated that the average denudation rate for the Darjeeling Himalaya is of

Impact of monsoon on Darjeeling Himalaya



There is no mountain range to protect the Teesta valley from the direct impact of the monsoon winds. The plains end abruptly at the Himalayan foothills, which receive exceedingly high bursts of rainfall.

the order of 0.5 mm to 5 mm during a normal year. But during a year of catastrophic floods such as 1968, the denudation rate for that year can possibly go up to 20 mm[33].

Explosive river

The explosive character of the Teesta valley can be attributed more to intense rainstorms than earthquakes. Landslides are common all over the valley. The area lies near Arunachal Pradesh where some of the world's worst earthquakes have been recorded[32]. Mild local tremors are felt several times a year even in the Teesta valley[34]. But most experts believe that intense rainfall is the main trigger for landslides and heavy erosion in the area.[35,36].

Monsoon rainfall is greater in the eastern Himalaya than in the western Himalaya[33]. But even within the eastern Himalaya, it is particularly intense in the Sikkim and Darjeeling Himalaya, which lie just above the alluvial plains of West Bengal. With Rajmahal hills situated to the west and the Shillong plateau to the east, there is no mountain range to protect the Teesta valley from the sweeping monsoon winds rising in the Bay of Bengal. The Jalpaiguri alluvial plains end abruptly as the ground rises by 125 m or more[30]. A sudden rise of over 2,800 m of elevation takes place between Siliguri and Darjeeling — a horizontal distance of barely 30 km[37]. The summer monsoon, therefore, directly hits the foothills and the lesser Himalayan ranges of Darjeeling just as it hits the southern slopes of the Shillong Plateau on which Cherrapunji, the world's rainiest place, is situated. Similar geographic conditions give the Teesta valley exceedingly high bursts of rainfall[37].

Table 17

Major cloudbursts in the Teesta valley

Date	Equivalent daily rainfall rate (mm)	
September 26-27, 1902	310	
June 11-13, 1915	690	
June 12, 1950	546	
October 3-5, 1968	1044	(Padamchen)
October 5-6, 1968	465	
August 5, 1969	1000	(Labha-Phaperkheti)
	742	(Aligarh-Gorubathan)
May 17, 1972	4032	
June 10, 1977	460	
May 20, 1978	1800	

Source : 27

RAINS OF TERROR

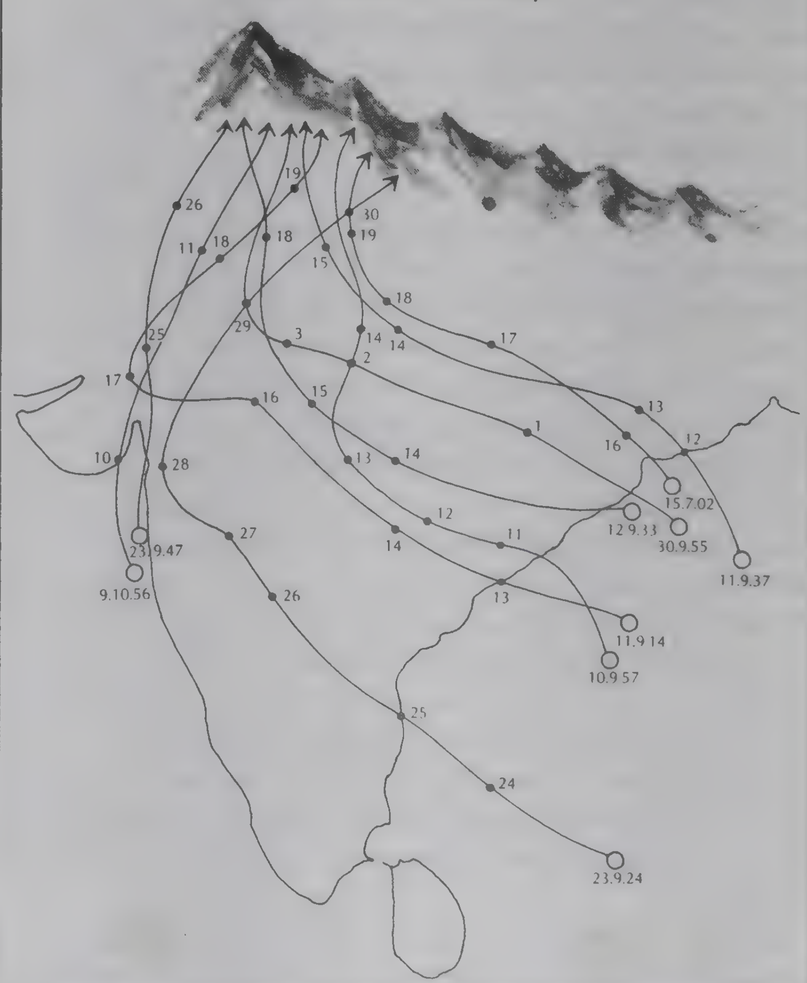
The two severest rainstorms in the central Himalaya were in September 1880 and September 1924. Widespread flash floods and landslides occurred during both and part of Nainital was washed away in 1880.

Some of the depressions, which form in the Bay of Bengal late in the monsoon travel westward, but after reaching east Rajasthan, sometimes swing back in a northeasterly direction towards the Himalayan foothills. They sometimes pass near the Arabian Sea and also draw moisture from it, shedding it in the Himalayan ranges, causing heavy floods even after the middle of September. Such rainstorms have occurred several times this century.

The 1880 rainstorm was of a two day duration while that of 1924 was of a three day duration. The former with its centre at Nagina, is considered to be one of the severest in the world of two day duration. Nagina in Bijnor district, located in the plains adjoining the Garhwal-Kumaon mountains, recorded 820 mm rainfall on September 18, 1880. This has not been exceeded so far.

The 1924 rainstorm, with its centre 64 km east of Roorkee, lasted over three days and it was the severest on record to have affected western Uttar Pradesh. A depression originated in the Bay of Bengal on September 23, which finally dissipated between September 28-30 in the Simla-Kumaon hills[1]. The Yamuna catchment up to Tajewala received heavy rains during the first two days. A peak discharge of 14,000 cumecs passed down the Tajewala headworks on September 28 and 22 km upstream the Yamuna at Paonta, rose by 13.1 m on the same day. Four days later, on October 2, the water level rose by 0.94 m above the danger level at the Delhi railway bridge[2]. Hundreds of people and thousands of head of cattle were washed away in Dehra Dun, Saharanpur, Ambala and Karnal districts. The mountainous portion of the Ganga basin up to Hardwar also received 350 mm rainfall in the three days of the storm[3].

Storms responsible for major floods in central and western Himalaya



Most storms responsible for floods in central and western Himalaya occur late in the year in September. After reaching east Rajasthan they swing towards the Himalaya, drawing moisture simultaneously from the Arabian Sea and shedding it in the hills.

Source : 2

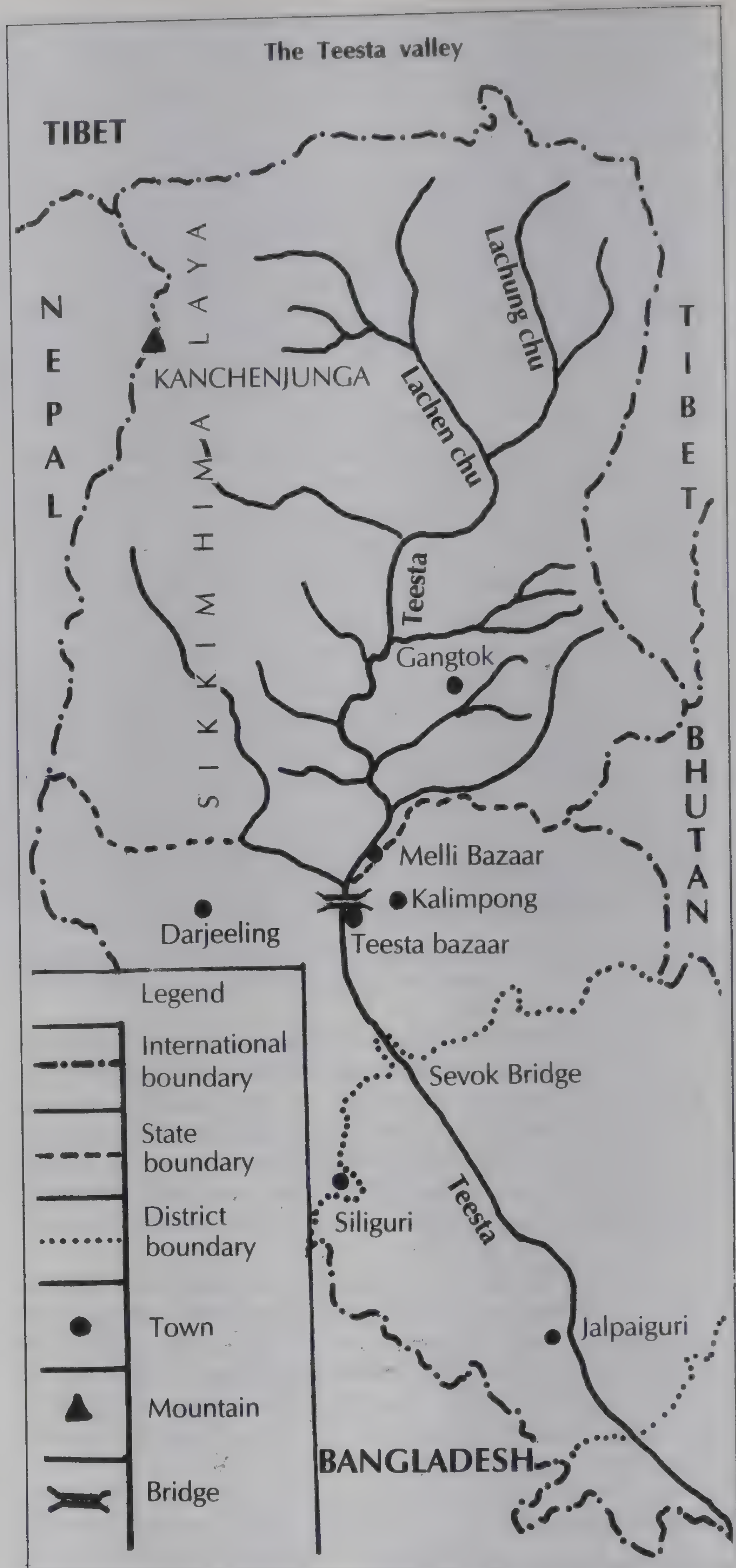
The area experiences rainfall varying from 3,000 mm to 6,000 mm every year. Cyclonic storms can last for two to three days and bring rainfall as high as 500 mm to 600 mm a day and over 200 mm over a period of just two to four hours[34]. Often the intensity of rainfall is so high that within 10 minutes of its commencement it can reach a burst of 750 mm per hour and this intensity is sometimes sustained for as long as three hours[37]. Between 1891 and 1965, rainfall intensities of more than 250 mm in 24 hours were recorded more than 40 times. One day rainfall has ranged from 310 mm to 1,800 mm and in one isolated case, it was as much as 4,032 mm (see table 17)[27]. Experts of the Central Building Research Institute (CBRI) argue that cloudbursts exceeding 1,000 mm in 24 hours will trigger landslides practically in any geological circumstance[27]. Some scientists have even argued that catastrophic rainfall events, such as the one in October 1968, are the primary slope forming processes in the region[33].

These landslides play a very important role in exacerbating floods. The blocking of the narrow gorge of the Teesta by massive rocks is common. Scientists have reported huge boulders up to 100 cum in size carried one km downstream in a single shower. Scientist R K Bhandari of the Central Building Research Institute has himself seen the 40 m wide Teesta river at the New Vong slide in north Sikkim virtually blocked for about 20 minutes in 1966[36].

Fragile geology

Three factors prevailing in Darjeeling and Sikkim Himalaya exacerbate the destabilising impact of high rainfall. Firstly, hills in the region are extremely fragile. The strata consists of sandstone, shale, mica schist and quartzite, which are in a disintegrated condition in many places and folded and thrusted with a number of fault planes[34]. Secondly, the topography is such that it leads to enormous erosion, toe cutting and landslides. The catchment of the Teesta in India is about 1.27 mha and in the hills alone it is about 0.8 mha[38]. Teesta originates at a height of about 6,400 m and is formed mainly by the union of two streams — Lacheng chu and Lachung chu — which unite at Chungthang[38]. Sikkim is like a bowl hemmed in by some of the world's highest mountains. To the west, the borders of Sikkim and the Teesta watershed abut the ridges of the mighty Kanchenjunga range and the boundary of Nepal; to the north and the east, the boundaries of Sikkim and the Teesta watershed lie astride the border with China and various high mountain ranges through which the earlier trade routes with Tibet lay; and, to the southeast, they merge with the border of Bhutan[37]. About one-third of the Teesta catchment is under perpetual snow. Snowfall occurs above the elevation of 2,700 m during winter [38].

Sikkim is mainly drained by the Teesta which travels through the centre of the state in an almost north-south axis. The Burhi Rangit, which drains a good part of western Sikkim, merges into the Teesta just south of Melli *bazaar* in the Kalimpong hills. Thus, every raindrop in Sikkim leaves the watershed at one point where Rangit and Teesta meet[37]. As the Teesta flows it meets several tributaries even though it is a small river. Its total length within the mountains is



about 200 km and it flows through steep gradients and narrow gorges, whose maximum width is 200 m[38]. Its tributary streams have steeper slopes and tiny catchment areas (see table 18). These streams can bring down large quantities of silt, boulders and water at a very high velocity.

They play a major role in causing floods during rainstorms. Several of them flow into the Teesta in an opposite direction. At their confluence, there is enormous turbulence and silt disposition. The narrow gorge of the Teesta tends to widen at such points because of the large silt deposits. But during the rest of its course, the river's

Table 18
Characteristics of the tributaries of the Teesta

Name	Catchment area (ha)	Length of stream (km)	Slope (m/km)	Discharge[1] (cumecs)
Larger streams				
Lachen Chu	1,87,920	72	98	5,250
Lachung Chu	94,870	67	85	2,655
Rangrang Chu	27,216	46	99	998
Ronghi Chu	96,940	64	73	2,198
Rangpo Chu	70,243	64	69	1,740
Rangit	3,08,190	83	81	7,193
Singhik	83,203	43	179	3,744
Smaller streams				
Geil Khola	2,707	10	186	405
Lepcha Jhora	400	4	285	63
Bhalu Khola	800	4.75	307	126
Khani Khola	425	4	290	67
Tar Khola	1,400	5.3	273	220
Tumthang Khola	1,800	7.5	245	275
Rani Khola	6,675	10	181	1,050
Rora Chu	6,800	17	193	1,056
Takchom Chu	3,600	13	182	570

Note: [1]Discharge figures have been calculated using a rainfall intensity of 75 mm per hour for one hour.

Source : 37

velocity is very high because of its narrow channel. The entire watershed is, therefore, conducive to quick runoff leading to flood peaks of short duration. The high floods, in turn, accentuate toe erosion and landslides.

As soon as the river enters the Jalpaiguri plains, it immediately spills into a width spanning 4 to 6 km braiding itself into four well defined streams separated by large silt fans. The river carries heavy silt and timber charge at this point because of the continuous erosion of the hillsides[37].

Because of these factors, the Teesta was considered wild and unpredictable even when its catchment was clothed with dense forests. Up to the close of the 18th century, the Teesta flowed into the Ganga but after the destructive floods of 1787 in which a large part of the Rangpur district was laid waste, it suddenly turned eastwards and joined the Brahmaputra[37].

Another set of factors which seem to have exarcerbated the erosion is the land use changes and development interventions that have taken place in the Teesta watershed. Sikkim has suffered extensive deforestation over the last 200 years. Pressures of land tenure and heavy state taxation in Nepal during the 18th century resulted in the migration of a large number of Nepalese subsistence farmers to Sikkim, Darjeeling, Assam and Arunachal Pradesh. Increases in area under subsistence agriculture were soon followed by widespread development of tea plantations after the British conquest especially in the Darjeeling Himalaya. These developments greatly reduced the forest cover in Darjeeling[33].

Changes in cropping systems are also adding to the problem. Many fields which were earlier under maize have been converted into paddy fields. The accumulation of water for eight to 10 weeks during the monsoon period tends to increase landslides. The area under irrigated cardamom plantations has also been increasing. Water is led to these plantations from perennial nalas, increasing percolation into the subsoil[34].

Only 36 per cent of Sikkim's area remains under forest cover, and extensive clearing operations continue, especially in more accessible southern districts. The northern forests, at higher elevations, are still reported to be in good condition. Over the past two decades, Sikkim has acquired one of the highest road densities in the Himalaya (12 km per 100 sq km compared with 0.44 km per 100 sq km in neighbouring Bhutan). This, in turn, has caused accelerated landslides and further loss of forest cover[33].

Highways and landslides

Highways in Sikkim and Darjeeling hills bristle with landslides. Extensive damage to roads in this region was first reported as far back as 1889. Numerous landslides continue to occur every year dislocating the communication system[34]. In 1973, the Siliguri-Darjeeling railway was damaged in several places because of rock falls and in 1968 and 1973, so were roads from Siliguri to Kalimpong and Gangtok. Disruption of communications leads to a drop in tourist revenue on which this area is heavily dependent[37].

Brigadier Harish Chandra of the BRO argues that highways themselves are the biggest cause of landslides[37]. R K Bhandari of CBRI claims that landslides on Sikkim highways represent some of the most challenging slope instability problems encountered in the Himalayan region. Another expert points out that "some of the formidable landslide complexes in the area are created by an unusual interplay of natural forces which no civil engineer would normally comprehend while designing the cutting of a highway"[40].

The national highway 31A, the major road in the area, takes off from Sevoke bridge and runs up to Gangtok. The first major landslide at Birik assumed serious proportions in 1968. The main cause is severe toe cutting by the Teesta. The overlying mass has been destabilised generating regular rock falls[37, 41]

After Teesta bazaar, there is considerable bank erosion. The river skirts around the Rinkingpong hill on which Kalimpong is situated. The river is continuously confined to a narrow gorge. Hill slopes on both sides are relatively gentle. There are thick forests on the western slopes up to an elevation of 1,700 m but the lower portions of the slopes from 1,700 m to 200 m have been cleared for tea gardens and paddy cultivation.

The hills consist of a thick alluvium overlay on impermeable rocks. Water percolation in this region is extremely high. Kalimpong hills on the eastern side are steeper. Vegetation is low and there are prominent faults. The streams descending from these slopes bring large masses of debris. Toe cutting and undermining of slopes is very high.

YAMUNA'S WRATH

Floods in the Yamuna catchment are closely related to meteorological phenomenon and their timing during the monsoon. Emerging from the Banderpunch glacier in the central Himalaya, the Yamuna is one of the biggest Himalayan rivers. Its 1.95 mha catchment up to Okhla in Delhi can be divided into two parts — the Himalayan, extending from the source to Tajewala, and the plains part from Tajewala up to Okhla. Within its Himalayan reach, the river has limited flood plains and because of high slopes, runoff is quick and heavy. Entering the plains near Faizabad in Saharanpur district after piercing the Siwalik hills — three km upstream of the Tajewala headworks — the Yamuna flows for 248 km to reach Okhla near Delhi. The river has no major tributaries in its plains reach up to Okhla.

The principal rainy months in the catchment are July and August. While the entire catchment receives an average of 1,171 mm of rainfall annually, the Himalayan part receives 1,458 mm and the plains part 826 mm. Short duration, high intensity rains are common. Dadupur, 21 km downstream of Tajewala, received 445 mm of rainfall on July 2, 1956. Delhi received 495 mm on September 9, 1875. Mussoorie, in the Himalayan reach has received 127 mm or more of rainfall in one day on 102 occasions between 1891 and 1960 and 254 mm or more rainfall on four occasions. Ambari, near the Siwalik hills, has received 127 mm or more on 82 occasions and 254 mm on five occasions. A study of all the peak floods shows, however, that they have rarely occurred in July. On 17 occasions between 1900 and 1960, the danger level of 204.8 m at the Delhi railway bridge was exceeded. This was mostly in August, September and October.

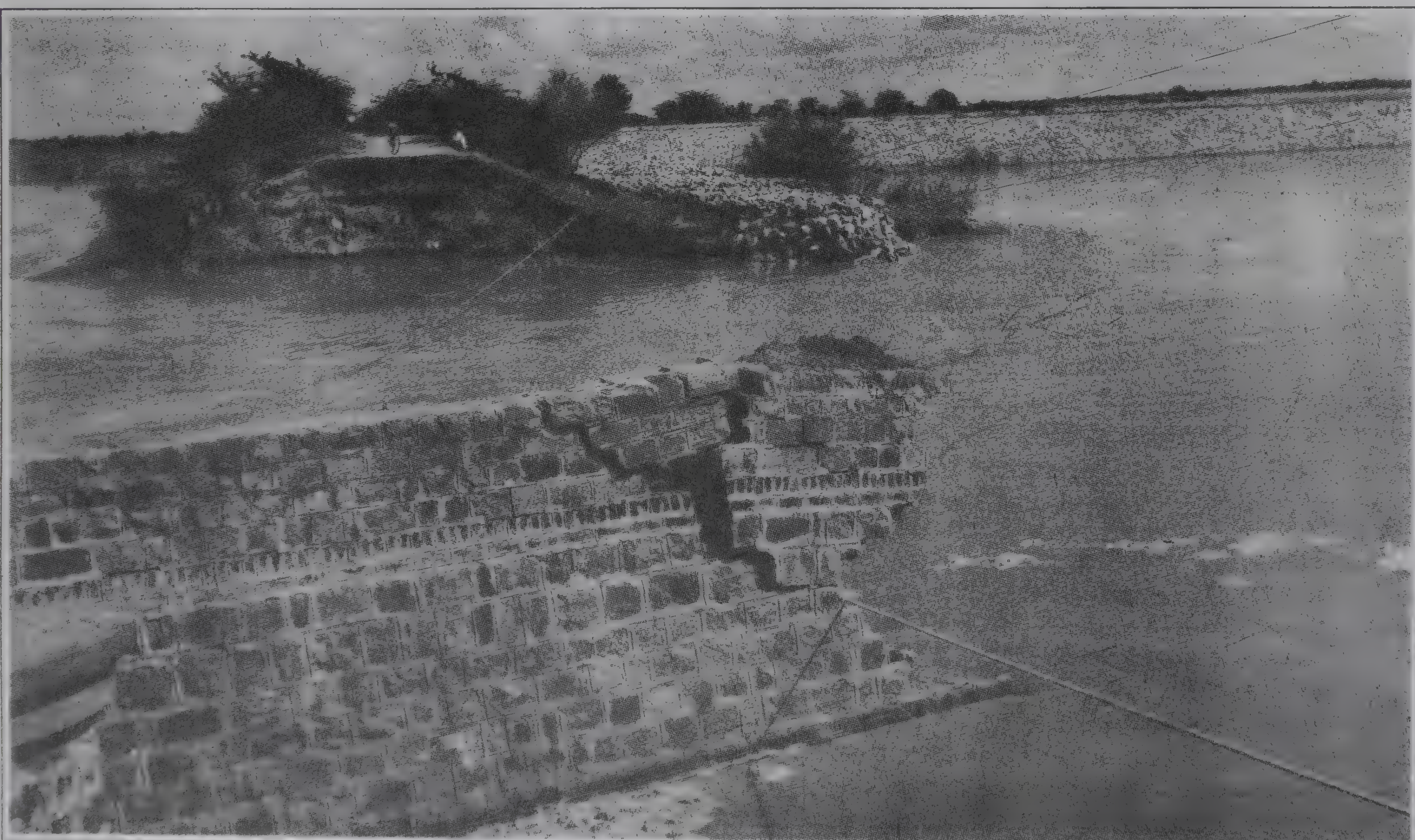
October is generally dry but sometimes heavy rains are

Floods in the Yamuna (1900-1960)[1]

	Monsoon period		
July	**August**	**September**	**October**
Mild floods[2]			
21.7.1902 (205.01)	4.8.1908 (205.2)	21.9.1900 (205.1)	none
	16.8.1942 (205.1)	23.9.1914 (205.0)	
	19.8.1943 (204.9)	13.9.1932 (204.9)	
	27.8.1948 (204.8)	23.9.1933 (205.0)	
	25.8.1952 (204.9)	20.9.1937 (204.8)	
	8.8.1958 (205.1)	18.9.1957 (205.1)	
Bad floods[3]			
none	none	29.9.1947 (206.1)	2.10.1924 (205.8)
			9.10.1955 (205.9)
			15.10.1956 (206.5)

Notes : [1] Danger level at Delhi railway bridge : 204.8 m
[2] 1 m above the danger level
[3] 1 m above the danger level

Source : 1



UNCONTROLLED FURY: An embankment breached by the Yamuna near Delhi.(PIB)

A few km upstream from Teesta bazaar, two streams, Lepcha Jhora A and Lepcha Jhora B, descend steeply from the Kalimpong hills. They bring so much silt that the river has developed a silt plain on its east bank and the river has been pushed westward and is now undermining the Teesta bazaar area. The Mangwa Jhora which flows in from the west has restricted the westward movement of the Teesta and, as a result, intensified the action of Lepcha Jhora B. The hill slopes of the Lepcha Jhora B, which has a tiny catchment of 200 ha, are so saturated with water because of irrigated fields that they are slumping into a mud flow.

All the way from Melli bazaar to Rangpo, there are more landslides. Near Rangpo, Tar Khola meets Teesta in the opposite direction and a large flood plain has been created at their confluence. At Rangpo, Teesta meets Rangpo chu, again in the opposite direction. The result is a large basin, almost one km long and 0.5 km wide.

Further up towards Gangtok, numerous new slides have taken place since 1970. The most famous of these is the Ninth Mile slide which acquired such a notoriety in Sikkim that for almost two decades, 1950s and 1960s, it was assumed that traffic must stop there in the rainy season. Scheduled buses used to stop at the slide for prearranged transshipment. The slide is situated below a cultivated hill.

The slopes remain saturated with water and the overburden continues to slump into the river. Below the hill, three streams that are insignificant in the dry season but carry enormous flows during the rains, meet the Teesta. During the rains, these three streams together contribute 25 per cent of the Teesta's flow at Rangpo. The slopes of these streams are steep and they bring mostly boulders into the river. This excessive flow has caused severe toe erosion[37].

Numerous landslides exist also on the north Sikkim highway from Gangtok to Chungthang. The problem at the New Vong slide consists of falling boulders ranging up to six metres in diameter which literally bomb the road and its associated structures.[35].

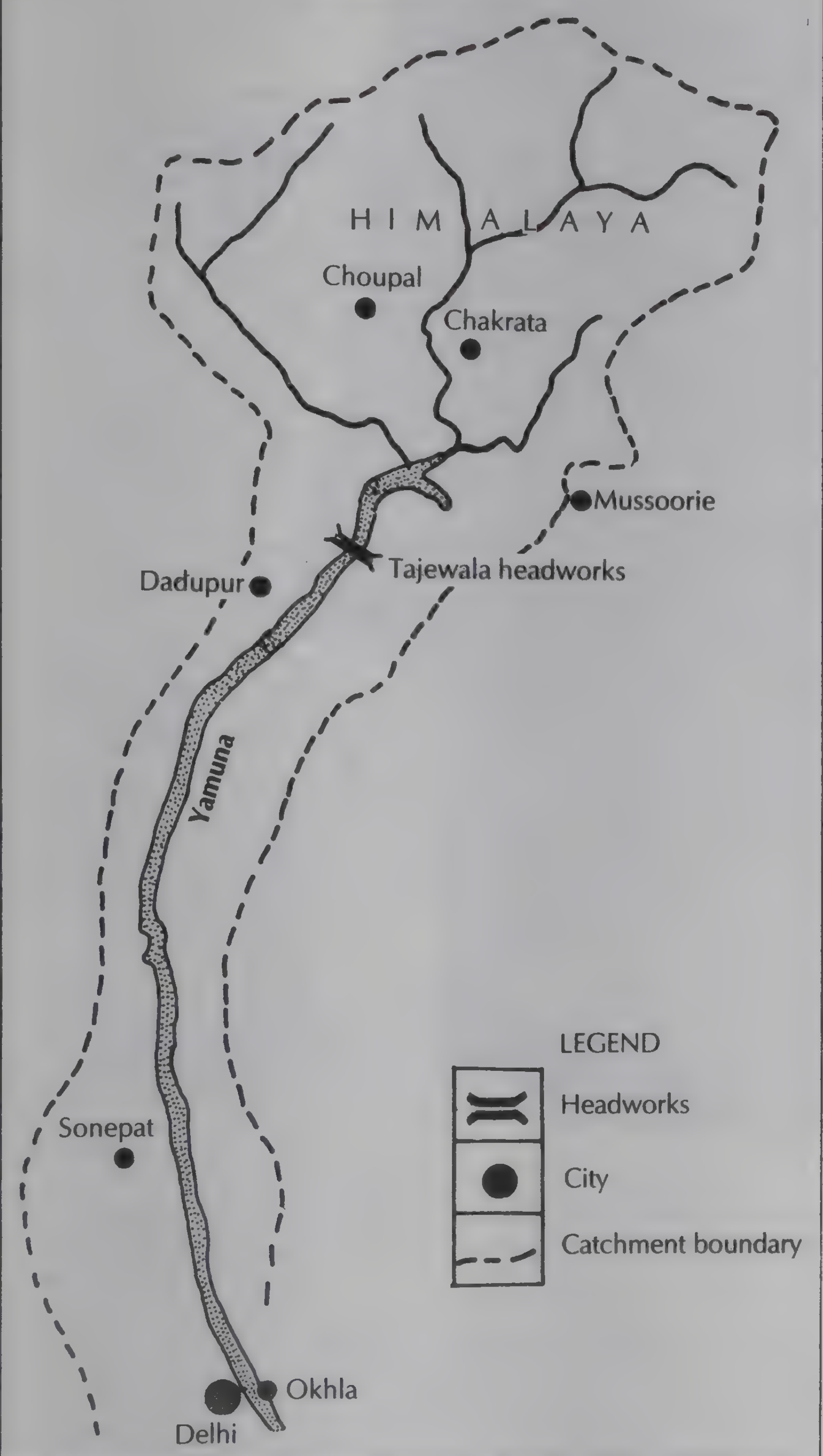
1968 Flood

The 1968 flood remains the biggest in recent years. In October 1968, rainfall between 600 mm and 1,200 mm fell in the Darjeeling Himalaya during a three day period at the end of the monsoon when the ground was already saturated. It is estimated that some 20,000 landslides took place. The 50 km road between Siliguri and Darjeeling was cut in 92 places and approximately 20,000 people were killed, injured or displaced[33]. R K Bhandari believes that these landslides played a major role in exacerbating the floods of 1968[36].

The October 1968 storm began on October 3 and lasted till October 5 but the peak flood passed down sometime on October 4[38]. Probably because the cloudburst was localised, very little damage occurred in north Sikkim up to Rangpo. All bridges, including one with just a four metre clearing above river level but situated two km above Rangpo, remained intact. However, the damage along the Rangpo chu and south of its confluence with Teesta was extremely severe.

Numerous bridges were washed away and rail traffic was

The Yamuna basin

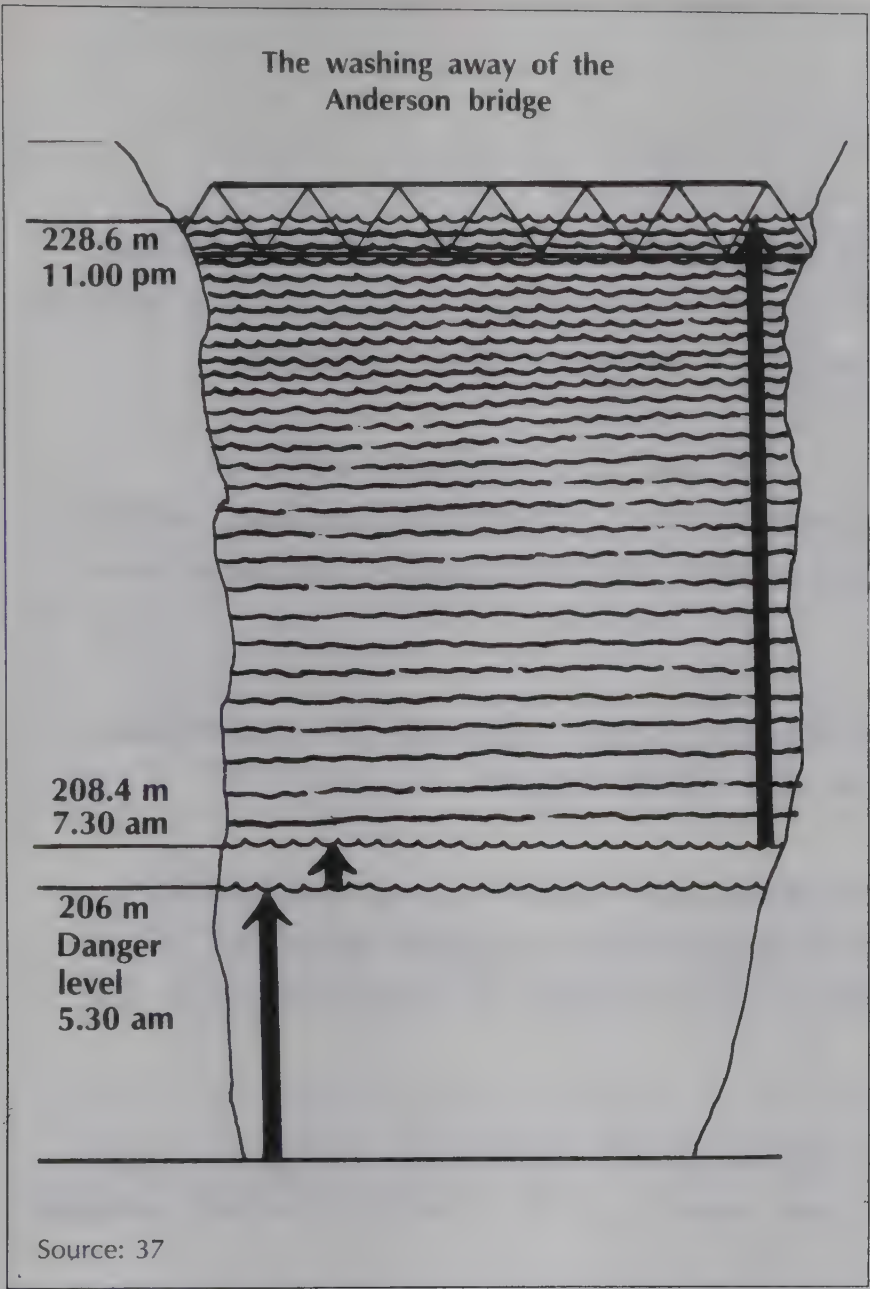


The Yamuna has a 1.95 mha catchment from its source up to Okhla in Delhi. The worst floods in the river have usually occurred in late September or October, as measured at the old railway bridge in Delhi.

received in the catchment in late September or early October. These, often result in heavy floods in the lower reaches because the catchment is almost saturated at that time and the river is nearly full. All the worst floods have been recorded in the last week of September and the first two weeks of October (see table 1). Floods of July, August and the first three weeks of September have all been comparatively milder.

The worst floods in memory — in 1924, 1947, 1955 and 1956 — were caused by monsoon storms breaking over the Punjab-Kumaon Himalaya or getting filled up over the plains of Punjab or northwest UP. If at the time of an approaching depression, a westerly wave happens to pass eastwards over the Punjab-Kumaon Himalaya, exceptionally heavy spells of rainfall take place. The floods of 1955 and 1956 were the result of this synchronisation of westerly waves with the filling up of depressions over the Punjab-Kumaon hills.

TRAIL OF TERROR: Floods in the Teesta leave behind a trail of devastation and impoverishment. (N Thiagarajan/Hindustan Times)



On October 4, 1968 the water level at the Anderson bridge rose by 22.6 metres above the danger level in 17 hours and finally the bridge was washed away.

closed for 32 days. Rangpo's lower market, which was well above the river before 1968, came under two metres of sand after the flood and is now almost at the same level as the river's flood plain. Parts of it have been since abandoned. Further downstream, enormous silt came down the Tar Khola and the road leading up to the bridge across it, was badly damaged.

The Tumthang khola, a minor nala, which has a small catchment of only 1,800 ha, met the swollen Teesta with a very heavy silt charge and a high velocity. It shed its silt charge in the resulting turbulence. So much silt was deposited at this site that no trace of a 30 m long bridge here could be found. It got buried under the silt. The bridge was exposed in the 1969 rains and then it was excavated. The bridge is still in service at the same site.

The old Anderson bridge at the Teesta bazaar was, however, not so lucky. With all small rivers coming down from Kalimpong hills going into spate, the average water level at Teesta bazaar, which is only about 190 m, began to rise at an alarming speed. The storm started on October 3 but by 0530 hours on October 4, the water level had already reached 206.4 m. It kept on rising rapidly and reached 228.6 m at 2300 hours — an incredible rise of 22.5 m in 17.5 hours. The river not only brought in a lot of silt but also trees.

The bridge at Teesta bazaar was safe even after the river had risen 20 m above the extreme danger level. The bridge may have remained safe if the water level had continued to rise and submerged it. Unfortunately, on the morning of October 5, timber logs and trees came down the river and got stuck against the bridge. As more trees collected, the bridge collapsed under the strain[37].

The flood waters, when they reached Jalpaiguri, overflowed the embankment and created wide breaches in it. The whole town came under two to three metres of water in the early hours of the morning and its residents were caught unaware. There was heavy loss of life and physical damages[42].

Landslides and floods have occurred several times since 1968. There were major floods in 1973 and 1975. In June 1976, the Teesta triggered off numerous landslides in Darjeeling. Several people were buried alive due to the caving in of a hillock[27]. While the earlier catastrophic floods were in 1950, the 1968 floods followed on rapidly with another catastrophic flood in 1973. Some, therefore, argue that the Teesta valley is becoming more flood prone.

However, stream flow data does not show that there is any demonstrable tendency for a trend towards higher water discharges[33]. It is, however, possible that the valley has become more prone to landslides because of extensive land use changes and development activities like construction of highways. To the extent that landslides tend to exacerbate floods in the mountains, the valley could indeed be becoming more flood prone too.

The above analysis clearly shows that the Himalayan valleys from Jammu and Kashmir to Arunachal Pradesh repeatedly face major floods. Usually caused by heavy and intense rains they become worse when associated with landslides and blocked river courses. Such floods have been taking place since time immemorial but the Himalayan valleys may have become more landslide and flood prone of late due to deforestation and development interventions.

- *Himalaya, the youngest mountain range in the world, is highly erosion prone. It is brutally lashed by intense rainstorms and it experiences some of the world's worst earthquakes. It thus constitutes an ecosystem primed for disaster.*

- *Himalayan mountains have risen one km in the last 1.5 million years, a phenomenon not older than prehistoric humans. This mountain building activity continues even today. Slopes become sharper and the mountains become more erosion prone.*

- *The 15,000-odd Himalayan glaciers cover about 17 per cent of the mountain area as compared to about 2.2 per cent in the Swiss Alps.*

- *A glacier dammed lake burst on the Tamur river in Nepal — a phenomenon known as jokulhlaup — and created a flood surge that stripped all trees 20 m above the river banks for 30 km downstream. The threat of jokulhlaups in the Himalaya is only being understood now.*

- *Major Himalayan rivers behave as erratically as small mountain torrents. Even the mighty Brahmaputra's stream flow in one year can be double that of another.*

- *Little is known about the hydrology of Himalayan slopes one study shows that less than one-fiftieth of rainfall in the lesser Himalaya gets converted into surface flows. Subsurface flows contribute significantly to Himalayan streams but also make the area very prone to landslides.*

- *Landslides contribute more to soil loss in the Himalaya than surface erosion. Deforestation is often blamed for landslides, but forests can only inhibit shallow landslides. They have little effect on deep landslides.*

- *During a normal year, some 0.5 mm to 5 mm of soil depth gets washed away in the Darjeeling Himalaya. During a year of catastrophic floods, such as in 1968, some 20 mm deep soil can get eroded. Hardly any mountain range in the world experiences such high erosion rates.*

- *Natural erosion processes in the Himalaya are so intense that they dwarf the changes caused by deforestation. Afforestation will help the local economy but will not prevent large floods in Himalayan rivers.*

CHAPTER 3

Deforestation : The Bare Facts

The Himalayan mountains are rising rapidly even as the seething rivers of the region erode them accounting for a quarter of the eight billion tonnes of sediment the world's oceans receive annually. Himalayan rivers, like Ganga and Brahmaputra, are also carriers of enormous quantities of water, causing havoc in the Indo-Gangetic and Assam plains.

There is a growing feeling that human intervention, resulting in deforestation is aggravating floods in the plains, as greater quantities of soil and water now rush down the Himalayan valleys to raise the river beds at an even faster rate.

However, to understand the mechanism at work an overview of the region's physiography, tectonics, geology, meteorology, hydrology and the process of erosion is necessary.

THE HIMALAYAN ENVIRONMENT

A series of three parallel mountain belts running along a grand arc for a length of about 2,400 km with a width ranging from 200 km to 400 km form the Himalayan system.[44] The northernmost belt is known as the greater, or high, Himalaya with numerous summits exceeding 7,500 m to 8,500 m. Their average height is about 6,000 m and they are among some of the highest in the world. Most of the greater Himalaya is situated above the treeline, which ends at approximately 4,000-4,500 m.

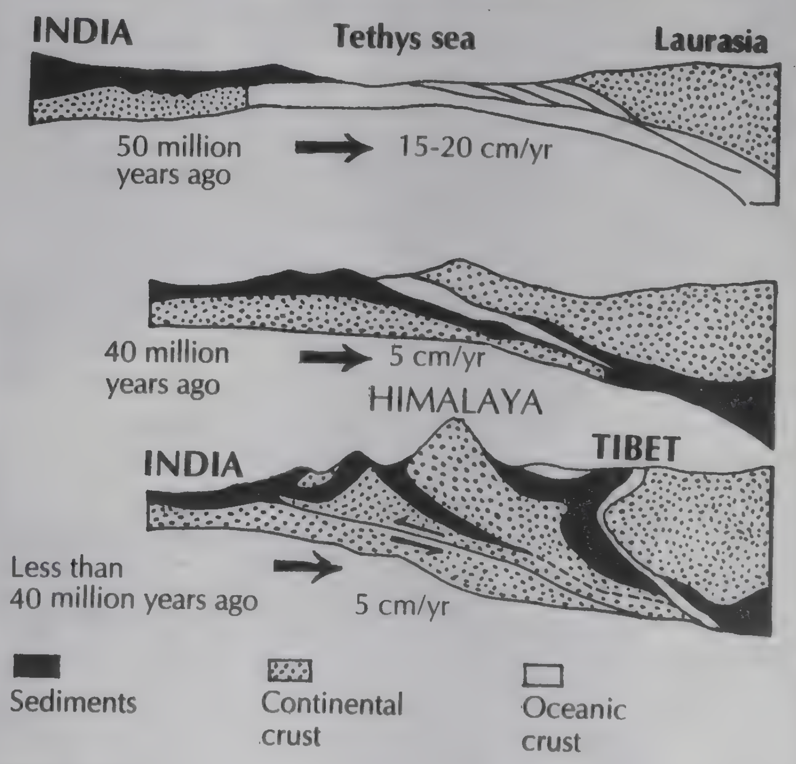
The southern flanks of the greater Himalaya merge with the lesser Himalaya or the so called middle mountains, whose average height is about 2,000 m to 3,300 m. The various ranges here have different names — for example, Pir Panjal in Jammu and Kashmir and Dhauladhar in Himachal Pradesh. The width of the lesser Himalaya varies from 60 km to 80 km. These mountains have traditionally had a high population density. The northern portion of the lesser Himalaya which lies between 2,900 m and 4,000 m still remains under upper montane forests. Below is a belt of intensive agriculture[33].

The Siwaliks constitute the outer Himalaya, which abuts the Indo-Gangetic plain. Rising abruptly from 200 m to 500 m they attain an height of 900 m to 1,200 m. Here occur the famous tectonic depressions known as the dun valleys supporting the richest agricultural land in the region. The duns range from Dehra Dun in India to the Rapti valley in Nepal. The width of the Siwaliks varies from 10 km to 50 km and they extend from the Brahmaputra valley in the east to the Potwar plateau in Pakistan[45].

The Himalayan mountains are the result of a massive collision of two drifting earth plates — the vast continental mass of Asia to the north and the smaller continental mass of the Indian peninsula to the south. About 100 million years ago, India lay in the southern peninsula. But after it broke away from the southern landmass called Gondwanaland, the Indian plate drifted northward at a speed of about 20 cm per year. After its initial impact with the Asian plate about 40-50 million years ago, it slowed down its northward progress to about five cm per year. But it has continued to move forward at the same average velocity ever since and, in the past 40 million years, plowed 2,000 km under present day Tibet[46].

This collision caused the Earth's crust to buckle and rise

The rise of the Himalaya



Source : 46

The collision of the Indian continental plate with the Asian plate resulted in the buckling of the Earth's crust to produce the Himalayan mountains. The process started less that 40 million years ago and is still continuing.

COMMON FLOODS: Floods are common in the Srinagar valley hemmed in between the Pir Panjal range to the south and the greater Himalayan ranges to the north.(PIB)

forming the Himalaya. The uplift has taken place in at least three distinct phases. The first phase took place about 38 million years ago. This gave rise to the greater Himalaya and the area north of it known as Transhimalaya. The second upheaval took place between seven and 26 million years ago and formed the ranges of the lesser Himalaya. The third, which formed the Siwalik hills started about seven million years ago. Huge amounts of sediments, washed down from the upper mountains, had accumulated in the shallow lagoon of water formed immediately to the south of the newly risen lesser Himalayan ranges. During the third phase, these sediments were lifted up to form the Siwalik hills[45].

The mountain building activity continues even today as the Indian plate thrusts itself further under the Asian plate. As a result, the Himalayan mountains continue to rise. Over the last 1.5 million years, the Himalayan mountains have risen at least 1,000 m — a phenomenon that is not older than prehistoric humans. In the last 10 million years, certain parts of the western Himalaya have been uplifted some three to six km. The Nanga Parbat, for instance, already the tenth highest mountain in the world, is still rising. In the past two million years, the uplift rate of the Nanga Parbat massif has, in fact, increased from 2.5 to five mm per year[47].

The current rate of Himalayan uplift is estimated to be seven mm per year. The mountains are eroded and washed down every year — drill holes have penetrated more than 5,000 m of alluvial sediments beneath the Ganga plains — yet several scientists believe that the height of the Himalayan mountains today is equal to, if not higher than, what it was a million years ago[33].

Because the Himalayan mountains constitute a region where two drifting earth plates meet and the Earth's crust is still undergoing a change, it is a region with high seismic activity. The junction of the greater and the lesser Himalayan regions is marked by a gently inclined thrust plane called the Main Central Thrust (MCT). The sliding of the Indian plate below the Asian not only led to the uplift of the great Himalaya but also resulted in widespread splitting, shearing, shattering and crushing of lesser Himalayan rocks. These weak rocks now easily give way under the onslaught of rains, shocks of explosions and earthquakes, and occasionally even vibrations generated by movements of heavy vehicles. As a result, this five km to 20 km wide MCT belt is marked by gigantic fans and cones of both ancient and recent landslides. The Main Boundary Thrust (MBT) zone defines the junction of the lesser Himalaya and the outer Himalaya and its geological condition is even worse.

The Himalayan region has been rocked by both moderate and large earthquakes with a magnitude of about eight on the Richter scale. Seismicity is high along both the MBT and MCT. Earthquakes have taken place along the MCT in Nepal and Himachal Pradesh. Earthquakes in the proximity of the MBT have been of larger magnitude even though their occurrence has been less frequent. There are strong and recurrent movements also along the many transverse faults which tear the Himalayan front into differentially moving blocks and segments. Seismicity maps show that the Indo-Nepal border registers the largest number of earthquakes per year. Large earthquakes have caused considerable damage to life and property through destructive landslides over extensive areas. It also seems that the transverse faults are seismically more active than the thrusts. It is through the valleys controlled by these faults that numerous Himalayan rivers emerge into the plains. Several dams and hydroelectric projects are also located here[14].

Seismic shocks in the Indian subcontinent

Source : 165

The Himalayan region has been rocked by both moderate and large earthquakes — the largest number being on the Indo-Nepal border — which have caused many destructive landslides. It is through these Himalayan valleys that numerous rivers emerge into the plains.

The geology

The Transhimalaya and the greater Himalayan regions constitute an extremely complex landscape, heavily sculptured by glacial erosion. The rocks range from hard granites and metamorphic rocks to those formed out of the sediments of the ancient Tethys sea, which once separated the Indian landmass from the Asian landmass and which disappeared with their collision. The entire region has been subject to extremely complex faulting, folding, and overthrusting because of the collision.

The rocks in the lesser Himalaya are also extremely varied and include sedimentary, metamorphic, and granites. However, there are also extensive areas of phyllites and schists — rocks which have a tendency to split very easily. These rocks are deeply weathered and, because of the steep slopes of the Himalayan mountains, highly susceptible to erosion.

The Siwalik hills contain the youngest and some of the most easily eroded rocks of the entire Himalayan region

SLIDING MOUNTAINS: Erosion is very high in the Siwaliks for they are made up of young and friable rocks but it is landslides which contribute more to soil erosion in the Himalaya. (Amar Talwar/CSE)

including unconsolidated sands and gravels. Where these ranges have been extensively deforested, there has been a catastrophic increase in soil erosion[33].

The meteorology

The Himalayan mountains are the critical determinant of the Indian subcontinental climate. In the winters, they serve as an effective barrier to the intensely cold continental air blowing southward into India. This helps to keep India warm in the winter. In the monsoon months, the Himalaya force the rain bearing winds from the south to deposit most of their moisture on the Indian side[48]. A monsoon simulation experiment conducted in the United States found that in the absence of the Himalayan ranges, South Asia would possess a desert like climate because the dry continental air flowing in from the northwest would push the rain belt far away to the south.

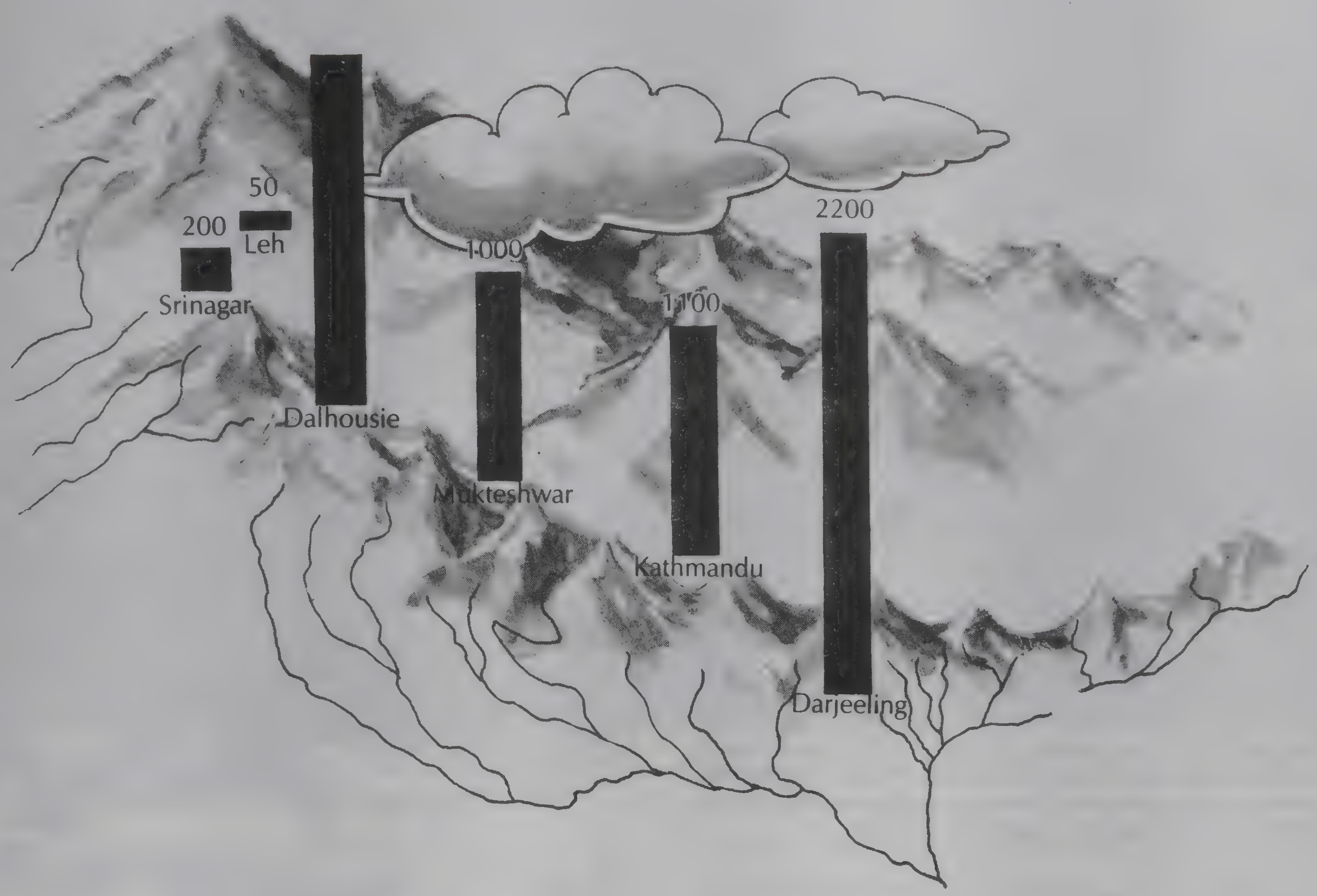
The weather within the Himalayan region changes considerably over the year. October and November are typically dry, but beginning December winter rains start, reaching a maximum around February. Snowfall sometimes continues up to April. March, April and May mark the transition period between the winter and the summer. Rising surface temperatures are accompanied by increasing thunderstorm activity, some of which bring hail. In winter, the Himalayan ranges receive precipitation from the mid-latitude westerlies. In the higher mountains, precipitation is typically in the form of snow, whereas in the lower valleys it occurs as rain. Winter precipitation in the Himalaya exhibits a decreasing trend from west to east.

The phenomenon is reversed in the summer. The eastern end of the Himalaya receives considerably more rain during the monsoon, where it also lasts longer. The monsoon commences in the first week of June in the eastern half, almost a month earlier, and ceases in September end, almost three weeks later, than it does in the western half.

Rainfall at the microlevel varies even more. Local mountains strongly modify its distribution. With minor ranges, spurs and valleys running in different directions, rain bearing winds can often enter only through narrow gaps from particular directions. Northern slopes and east-west oriented valleys usually receive less precipitation because of the rain shadow effect than southern slopes or north-south oriented valleys[48].

Any detailed study of rainfall needs a dense network of observatories, which do not exist in the Himalayan region due to difficult terrain and inaccessible areas. It is, therefore, not possible to correctly estimate rain or snowfall distribution in most Himalayan catchment[49]. In the hilly portion of the Yamuna catchment, there is not even one raingauge for every 300-400 sq km of the catchment area as recommended by the World Meteorological Organisation. In fact,

Rainfall variation across the Himalayan range (in mm).



Source : 48

The eastern end of the Himalaya receives considerably more rain in the monsoon where it also lasts longer than the western half. The monsoon commences a month earlier in June and ends in September, three weeks later than in the western half.

Indian meteorologists believe that given the extreme variability of rainfall in the Himalayan catchment, the density of raingauges should be one for every 150 sq km[50].

Rainfall also varies with altitude. Analysing data obtained from the Kosi basin, meteorologists O N Dhar and B K Bhattacharya found that maximum rainfall occurs at two different elevations. The first occurs near the foothills and then starts decreasing, reaching a minimum at an elevation of 600-800 m. This region is located on the leeward side of the Siwalik hills, that is, in the valleys between the Siwalik and the lesser Himalayan ranges.

Thereafter, rainfall starts increasing until an elevation of 2,000-2,400 m is reached. The lesser Himalayan ranges, therefore, receive high rainfall. The rainfall again decreases, probably because the winds lose most of their moisture while moving over the outer and lesser ranges[51]. The Mount Everest region in the greater Himalaya, for instance, is almost a semi-arid area. The 3,000-4,000 m high Pir Panjal range literally acts as a barrier to monsoon winds entering the Kashmir valley, which lies between the lesser Himalayan and the greater Himalayan mountains. The area to the south of the range receives four times more rainfall than the area to its north during the monsoon[52].

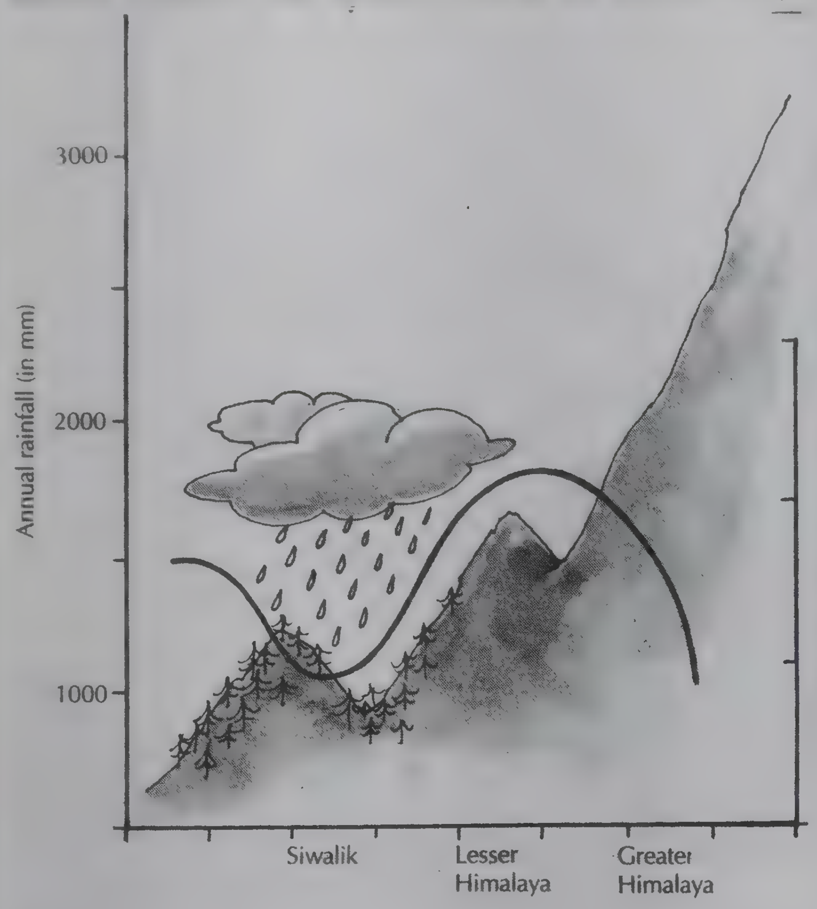
The greater Himalayan mountains themselves stop almost all the monsoon winds from reaching the slopes which face Tibet. These slopes tend to be semi-arid to extremely arid because of the rain shadow effect. Ladakh, for instance, is a cold arid desert.

The rainstorms

Summer rain in the Himalaya, as in the plains, is regulated by the oscillations of the monsoon trough (area of low pressure) and other perturbations in the monsoon circulation, such as the formation of depressions in the Bay of Bengal and their movement along the central parts of the country and the Indo-Gangetic plains, and breaks in the monsoon. The depressions bring fresh surges of monsoon air, and when these get blocked by the Himalayan ranges, they pour heavy rain over them.

Short duration, high intensity rains are common over the Himalaya. For example, the town of Mandi and the Suketi valley in Himachal Pradesh experienced an unprecedented

Rainfall variation with elevation across the Kosi Himalaya



Source : 51

Rain bearing winds lose their moisture as they cross the Siwalik. Heavy rainfall occurs near the foothills and then starts decreasing. Thereafter it starts increasing again and the lesser Himalaya receive substantial rainfall. By contrast the greater Himalayan regions are very dry.

rainfall of 250 mm in three hours in the early hours of August 31, 1960 [53]. Hardwar received 495 mm of rainfall in 24 hours on September 18, 1880 and Dehra Dun received 487 mm rainfall in 24 hours on July 25, 1966. Once every 10 years, the Ganga basin up to Hardwar sees a rainfall event of 100 mm to 300 mm in one day and once in 100 years, a one day rainfall of as much as 200 mm to 450 mm [52a].

The Beas catchment regularly witnesses rainstorms. Dharamsala, located on the southern slopes of Dhauladhar range, received 387 mm of rain in one day on July 16, 1934 and 363 mm on September 21, 1917. It received over 76 mm of rainfall every tenth day of July and August, on average, in the 60 years between 1901 and 1960 (see

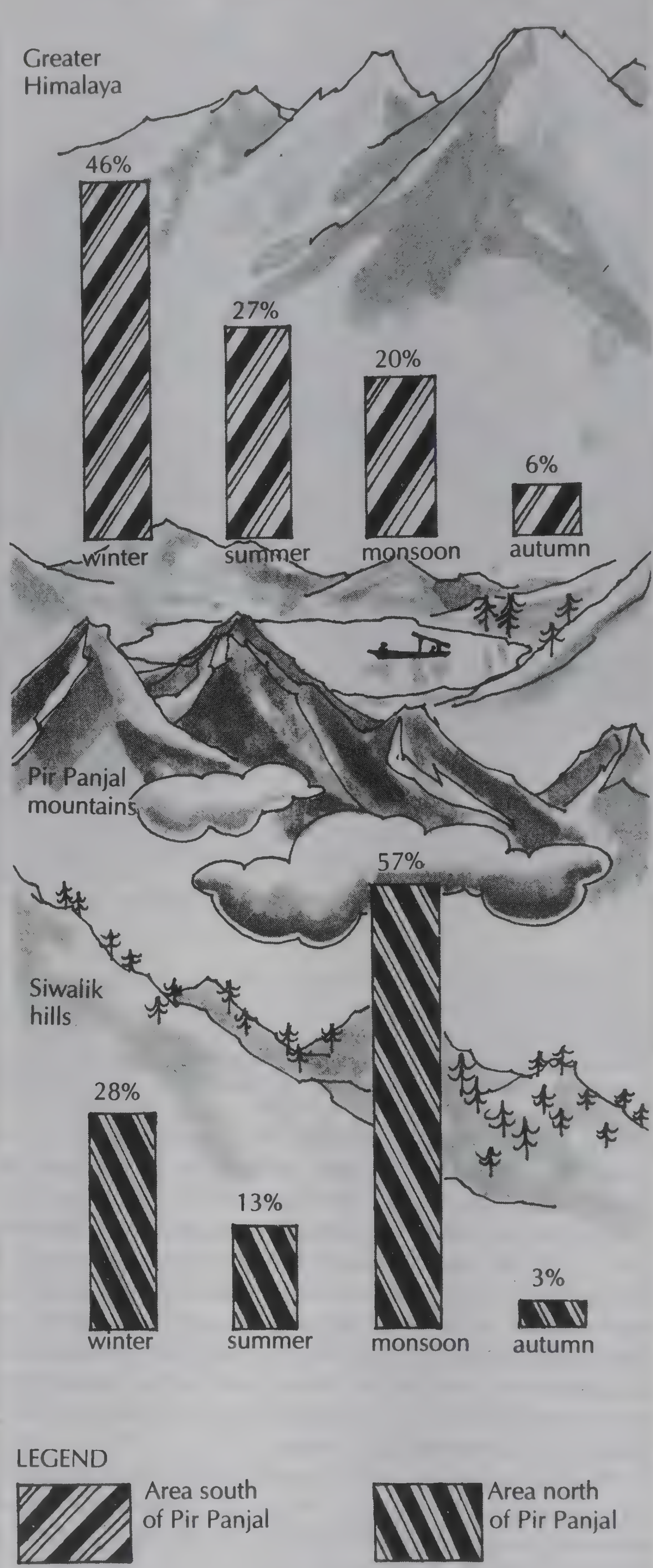
Table 19

Heavy rainfall events in the Beas catchment

Station	Rainfall events (76 mm or more) from 1901-1960			
	July (1860 days)	August (1860 days)	September (1800 days)	October (1860 days)
Dharamsala	212	228	58	5
Kangra	109	158	48	3
Palampur	164	172	36	7
Hamirpur	48	61	16	4
Dehra Gopipur	45	68	23	7

Source: 54

The rain shadow effect of the Pir Panjal



Source : 52

The 3,000-4,000 m high Pir Panjal range acts as a barrier to monsoon winds entering the Kashmir valley, which makes the state a popular tourist resort during the monsoon months. The area south of the range receives four times more monsoon rainfall.

DEEP FREEZE: A large part of the Himalayan range is covered by glaciers — a major source of water for the mighty rivers that flow into the Indo-Gangetic plains.(Anil Agarwal/CSE)

table 19)[54]. Whenever a monsoon depression over the Punjab Himalaya coincides with the passage of a western disturbance moving eastwards, exceptionally heavy rains occur in the Beas catchment.

During monsoon breaks, the axis of the monsoon trough tends to lie at the foot of the Himalaya instead of over the Indo-Gangetic plains. The trough axis is the line along which the two branches of the monsoon, namely, the Arabian Sea and the Bay of Bengal, meet. At such times, central India experiences near drought conditions. But in sharp contrast, the mountains of the eastern Himalaya tend to get heavy to very heavy rains. Because of this, a peculiar situation is created on a 'break day' in the catchment of Himalayan rivers, particularly those located in Sikkim and Nepal. These rivers often go in spate while downstream plains are experiencing almost drought conditions.

On a 'break day', the entire Himalayan region does not experience an increase in rainfall. The region to the west of longitude 79°E, that is, western Himalaya actually witnesses a general decrease. But rainfall increases to the east of longitude 79°E and maximum increases — 200 per cent to 300 per cent over the average — are located in the region between longitudes 85°E and 87°E, where the catchments of Teesta, Kosi and Bagmati lie. Rain also increases in the catchments of the more western rivers like Gandak, Rapti and Ghaghara but not to the same extent[55].

The glaciers

Himalayan glaciers cover about three mha or about 17 per cent of the mountain area as compared to 2.2 per cent in the Swiss Alps. The 15,000 odd Himalayan glaciers form a unique reservoir which supports such mighty perennial rivers as Indus, Ganga and Brahmaputra. Unfortunately, data on the greater Himalayan environment is fragmentary. Himalayan glaciers are spread over a chain of mountain ranges with different orientations and elevations, which makes the task of data collection extremely difficult.

The glaciated area, including the area north of the Himalaya which drains into Himalayan rivers, is estimated to be about five mha. About 10 times the glaciated area gets snow covered during the winter months. The annual water yield from glacier-melt is about 15 mham per year. The snow melt contributes another 50 mham. Thus, on a very rough estimate, snow melt and glacier melt together contribute a water volume of 65 mham to the northern rivers. About 70 per cent to 80 per cent of all these contributions come during June to September. These figures are comparable to the total volume of water being used in India at the moment[56].

Little is known about the contribution of glacier and snow melt to specific rivers but a study recently conducted on the Dhauliganga river, which originates in the lesser Himalaya in Pithoragarh district of Uttar Pradesh, shows that these cannot be major causes of floods. The river's catchment is studded with 23 small and medium glaciers. About 45 per cent of the annual river flow comes from glacier and snow melt.

The average daily glacier melt from April to September remains fairly constant, about 45-55 cumecs. The peak occurs after noon but it affects, the downstream reaches of

the river only around midnight. Snow and glacier melt together contribute a maximum of 75 cumecs (that is, about two per cent) to peak river flows which are of the order of 3,500 cumecs. The Dhauliganga study, thus, shows that despite a large cover of snow and glaciers, Himalayan floods are mainly due to rainfall[57].

The jokulhlaups

However, there are rare occurrences when glacier dammed lakes can suddenly burst — a phenomenon known as *jokulhlaup* — to cause severe floods. Major jokulhlaups are not uncommon in the Himalayan ranges though little has been known about them until recently. A moraine dammed lake drained catastrophically on August 4, 1985 in a tributary valley of the Bhote Kosi in Nepal. As scientific curiosity grew, it was found that at least three jokulhlaups, and possibly five, seem to have occurred in the region within living memory.

Villagers in the Dudh Kosi valley can remember at least two major floods caused by glacial dam bursts — one about 60 years ago and another in 1977 when an ice dammed lake at Mingbo burst. Both floods caused immense havoc and extensive erosion in the Dudh Kosi valley, depositing vast amounts of sediment[58]. In 1981, a glacial lake outburst occurred in the headwaters of the Sun Kosi river, which damaged the Sun Kosi barrage and a large number of old landslides were reactivated[59]. A glacial dam burst on the Tamur river in Nepal resulting in a flood surge that for 30 km downstream stripped all trees 20 m above the river bank [60]. Indian hydrologists have also recorded a jokulhlaup on the Dhauliganga, but fortunately its peak was not very high[57].

One of the most spectacular geomorphic events to have occurred in historic time in the Nepal Himalaya was the outburst of a moraine dammed lake behind the Machapuchare mountain between 600 and 800 years ago. The resulting flood surge down the Seti Khola which deposited 5,500 m cum of debris in the Pokhara valley, damming lake Phewa. This is the largest known glacier lake outburst.

Several Himalayan glaciers are retreating. A recent study has concluded that these glaciers have been in a general state of retreat since 1850. The rate of retreat varies from 4.6 m to 23.5 m per year. Glaciers in the Kosi watershed have also been thinning and retreating since about 1900. The progressive retreat and thinning of Himalayan glaciers during the present century is resulting in the formation of new moraine dammed lakes and the enlargement of preexisting ones. Small ponds on the surface of lower glacier tongues are also enlarging and coalescing. A new lake has formed since 1956 on the lower part of the Imja glacier below Lhotse. It is now about 50 ha in extent. A cursory study of the Dudh Kosi and Arun catchment in eastern Nepal-southeastern Xizang has revealed the presence of at least 50 ice dammed and moraine dammed lakes. While little is known about the frequency of collapse of these ice and moraine dams, their sheer number is definitely impressive[33].

The hydrology

The Himalayan range can be divided into three huge watersheds of the Indus, Ganga and Brahmaputra. Amazingly, all these rivers have their sources very close to each other in the central Himalaya. Four of the world's greatest rivers — Karnali, Indus, Sutlej and Brahmaputra — rise from the watershed of one mountain, mount Kailash. The fifth, Ganga, emerges at Gangotri, about 60 km away.

Indus and Brahmaputra probably came into being 20 to 40 million years ago as the greater Himalaya was being

The Himalayan states

NEPAL'S NIGHTMARE

On August 4, 1985 a moraine dammed glacial lake, Dig Tsho, burst in the Khumbu Himal area of eastern Nepal. The formation of glacial lakes largely depends on glacial activity. Glaciers can advance or retreat due to changing climatic conditions and while retreating can easily form moraine dammed lakes.

Swiss scientists Daniel Vuichard and Marcus Zimmermann studied the 1985 Khumbu Himal catastrophe in detail[1,2]. The Dig Tsho lake had been impounded by the moraines of the Langmoche glacier probably within the last 25 years. The lake surface was about 50 ha in area, one-third was covered by an ice mass about 300 m wide and 500 m long, the maximum depth of the lake was 18 m. The moraine dam, which held the lake, was 60 m in height at its lowest point consisting of two to five m diameter boulders and gravel set within a mica sand matrix of soil.

The Khumbu Himal valley receives little rain because of the rain shadow effect of the neighbouring high mountains. Good weather prevailed on August 4, 1985 and solar radiation was intense. The supply of melt water from the glacier must have been high. Before the burst, the lake was full to its brim. Just then an ice avalanche from Langmoche glacier fell into the lake sending a five m impulse wave across it. The Dig Tsho burst and within four to six hours, the lake emptied into the Langmoche valley, one of the tributary valleys of the river Bothe Kosi, which flows along many Sherpa settlements.

Six mcum to 10 mcum of water plummeted along the Bothe Kosi and then into the Dudh Kosi in four hours and the initial peak discharge was at least 2,000 cumecs. The flood caused significant damage for more than 80 km of the river course till the confluence of the Dudh Kosi with the Sun Kosi. Eye witnesses report that the flood surge moved down the valley like a huge "black" mass of debris.

There were several separate surges. Many bridges were not destroyed until 30-90 minutes after the passage of the initial surge. Trees and large boulders were dragged and bounced around. emitting a loud noise "like many helicopters" and a foul muddy smell. Where the river flowed over bedrock, the topsoil cover was washed off and the bedrock surface was polished at river bends. Slopes, which were made up of loose material, were subject to heavy undercutting, even if they had a good tree cover.

This caused landslides several metres deep and several tens of metres high. It is quite possible that temporary damming of the river channel also took place because of landslides. Some houses were toppled by the vibrations caused by the flood surge. Lateral erosion destroyed several houses even if they were not situated immediately along the river bed.

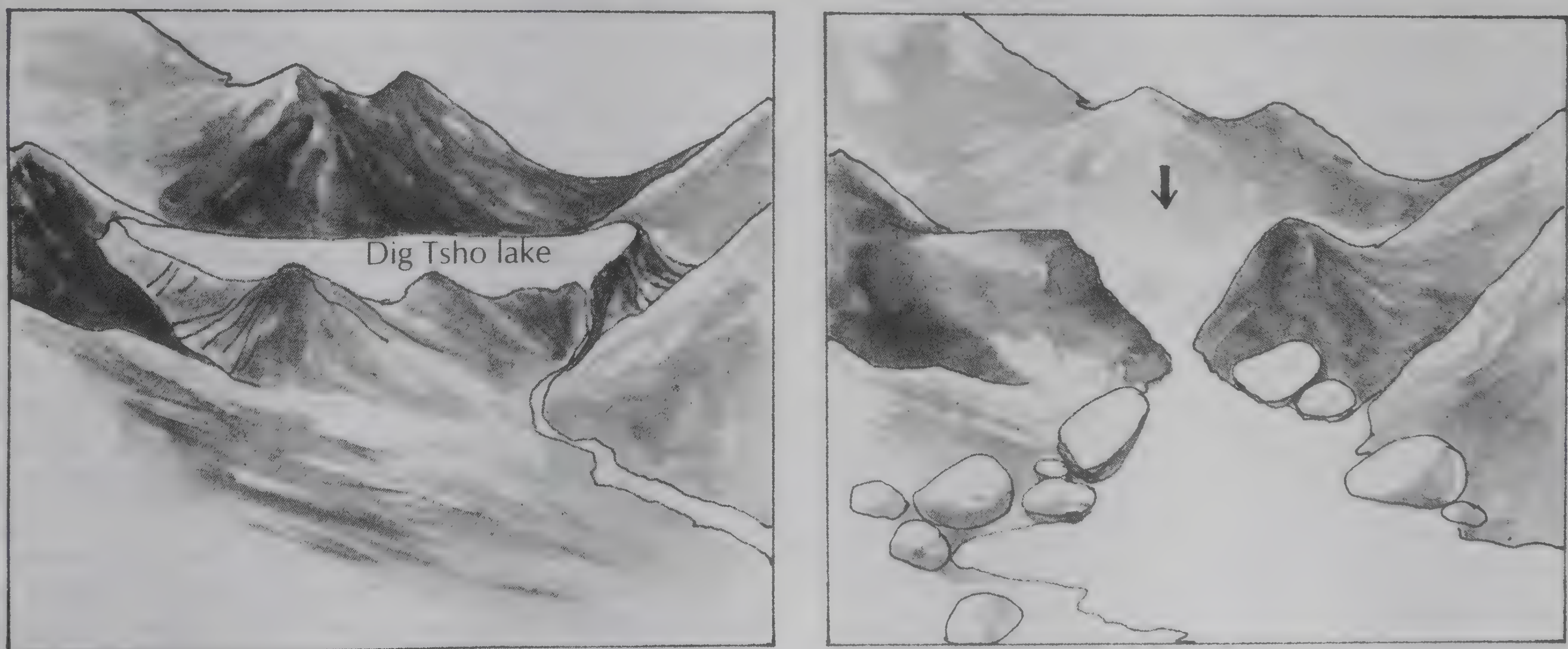
In other places,houses slid on to the river bed as a result of landslides during the event or from progressive sliding that lasted for days. Some 3.3 mcum of soil and rocks was moved around within a distance of 40 km and about 10 to 15 per cent of this was carried away further by the river.

All 14 bridges along the flow were destroyed, entire trails disappeared, mass erosion devastated trees, terraces and houses. The nearly complete Namche hydroelectric power plant was destroyed. Loss of human life, however, was remarkably low because most people were at home to observe a festival.

Vuichard and Zimmermann argue that sudden outbreaks of glacial lakes occur throughout the Himalaya and future occurrences must be anticipated. Glacial lakes are increasing because of the continued thinning of glaciers. Thus, it is likely that frequency of outbursts will increase.

Many of the glaciers occur in deeply eroded basins at the foot of high mountain cliffs. The lakes at their bottom can be reached by avalanches from the slopes above. There are hundreds of dammed water masses in eastern Nepal. In Khumbu Himal and adjacent areas, many lakes of comparable size to Dig Tsho can be identified.

Dig Tsho glacier dam burst in Nepal



Source : 2

On August 4, 1985 the moraine dammed Dig Tsho lake in Nepal burst and emptied out through a 60 metre high breach, destroying 14 bridges in its wake and creating enormous havoc.

formed to drain the new highland near mount Kailash. The Sutlej and Indus flow westward from their sources to meet on the dusty plains of Punjab and flow on into the Arabian sea.

Brahmaputra flows eastward along the boundary between the Indian and Asian plate. It forms a loop around the Himalayan mountains to flow through the narrow Assam valley and finally link up with Ganga before entering the Bay of Bengal. Together, Ganga and Brahmaputra form a garland around central and eastern Himalaya.

These awesome mountains and the mighty, perennial rivers they give rise to, have been the subject of more myths, legends and prayers than any other mountains or rivers in the world.

Even though they are largely fed by the summer monsoon, these rivers remain perennial because of the huge Himalayan glaciers. Without them, the Indo-Gangetic plains, which support one of the highest densities of human population in the world, would be a desert. But while the Himalayan rivers have been a source of life, they have also given birth to enormously destructive floods.

River discharges increase considerably during the monsoon. The flow is punctuated by sharp peaks of high flood flows of short duration. Flows also vary sharply from one year to another. Even in a large river like the Brahmaputra, annual stream flow can be more than double in one year as compared to another. As one scientist puts it, even major Himalayan rivers often behave like mountain torrents.

As a result, averages of data collected over a short duration are often extremely erroneous in the Himalayan context. Recent studies conducted on Beas, for example, show that the flood data used to build the dam at Pong — one of the biggest in the country — in 1974 was an underestimate[62]. When the dam was being built, little hydrometeorological data was available. The data after construction shows that the severest flood of 1947, which was used to determine the design inflow flood for the dam, was exceeded in 1976, 1977 and 1978.

Table 20

Denudation rates in the Himalaya

Location	Denudation rate (mm/yr)	
Himalaya	1.00	Regional
Ganges/Brahmaputra watershed	0.70	From present rate of influx to Bay of Bengal fan
Hunza watershed	1.80	From sediment yield
Tamur watershed	5.14	From sediment yield
Tamur watershed	4.70	From sediment yield 1948-50
Tamur watershed	2.56	
Arun watershed	1.90	1947-60
Arun watershed	0.51	
Sun Kosi watershed	2.50	
Sun Kosi watershed	1.43	
Sapt Kosi watershed	0.98	From suspended sediment
Sapt Kosi watershed	1.00	
Karnali watershed	1.50	
Darjeeling area	0.5-5.0	Forested/Deforested
Darjeeling area	10-20	In catastrophic storms

Source : 33

The hydrology within the Himalayan mountains is also extremely complex. Recent studies show that most of the rain that falls on Himalayan slopes gets turned into subsurface flows. Kumaon university scientists recently measured surface flow from eight forested and five non-forested sites. They found that only 0.3 per cent to 1.3 per cent of rainfall got turned into surface flows. The non-forested sites had greater surface flow but their magnitude was still very small.

They, therefore, concluded that most water that flows into Himalayan streams comes from subsurface flows and that surface flows are too small to play a significant role in either causing floods or soil erosion. But because soil cover in most areas is shallow and lies over soft, quick weathering rock, subsurface flows make the mountains greatly susceptible to landslides.

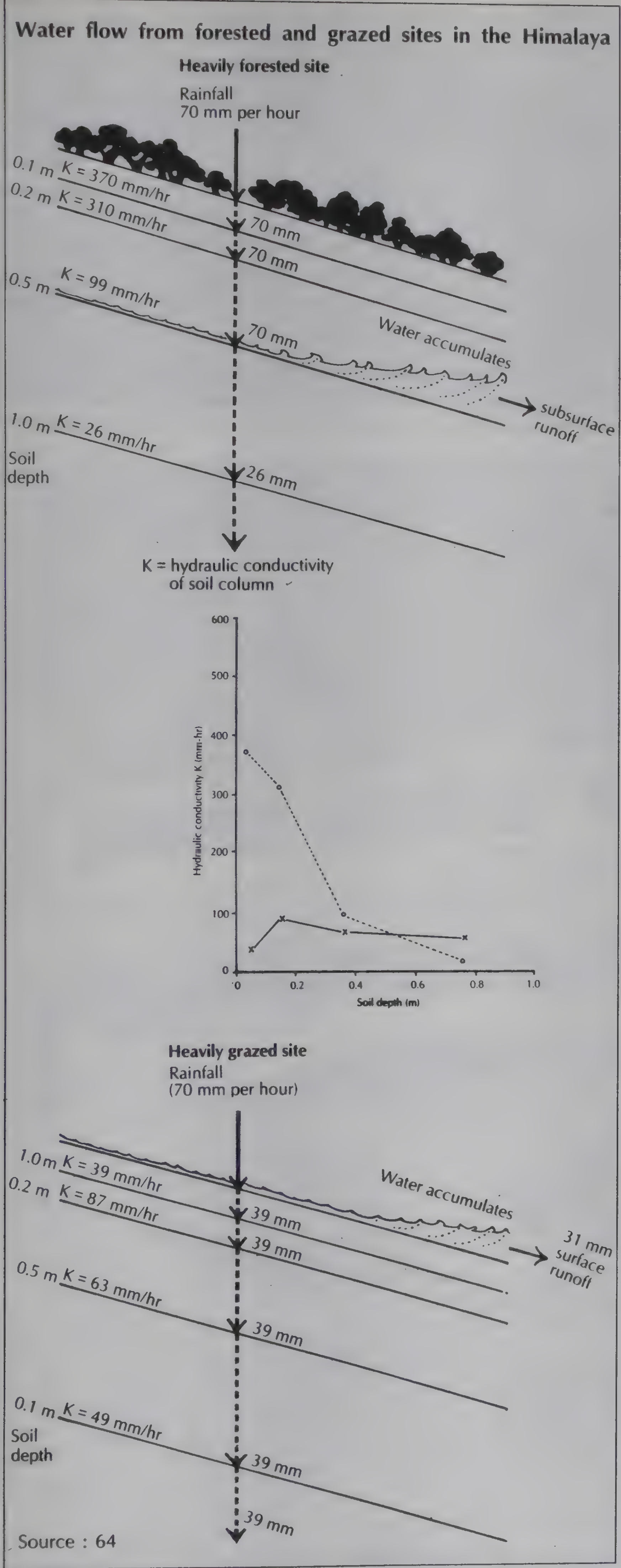
A study carried out by scientists in Nepal concluded that even heavy storms should not produce much surface flow, including areas that have been deforested and converted into heavily grazed and trampled grassland. The team measured the infiltration rates at five sites with different types of forest cover. The most degraded site revealed the lowest infiltration rate in the top layer of the soil — only 39 mm/hr — and a site with a well protected pine forest showed the maximum rate of 524 mm/hr. But available data revealed that few rainstorms would exceed the infiltration rate even at the most degraded sites. Surface runoff from these slopes would, therefore, be rare and small, and the presence or absence of a forest would do little to increase or decrease it[64].

Other scientists have, however, argued that higher surface runoff has been seen in higher rainfall areas than those chosen by the above team[65]. The controversy notwithstanding, the available evidence does show that subsurface flows play an important role in Himalayan hydrology.

Soil erosion

All processes of soil erosion — surface erosion, erosion by rivers and mass movements — are at work in the Himalaya. Mass movements include dramatic processes such as landslides, mudflows, rock falls, and rockslides. While surface erosion is primarily a product of reduced vegetation cover, mass movements are the result of gravity. While the first can be influenced greatly by human action, the second is more the result of natural forces.

Soil loss takes place on all slopes. But the intense soil erosion in the Himalayan mountains can be gauged from the denudation rates prevalent in the region. Denudation rate is a term used to describe the lowering of the landscape due to soil loss. It is usually calculated in terms of mm per year of surface lowering averaged over a watershed. Regional denudation estimates are usually derived by measuring the sediment being moved out of the watershed



Hydraulic calculations show that the presence or absence of a forest will do little to increase or decrease runoff from Himalayan slopes. Water will run off over the surface in a grazed area and below the surface in a forested area.

by the main river channel. The denudation rates in the Himalayan mountains are estimated to be "up to five times or more than general estimates of erosion even in areas of steep relief", according to geographers Jack Ives and Bruno Messerli, in their recent book *Himalayan Dilemma*. Several denudation rates are available for different parts of the Himalaya. Despite their wide range from 0.5 mm/yr to 20 mm/yr, these figures are very high when compared with data from other parts of the world. The Alps, for instance, have an overall rate of one mm/yr. Figures above six to seven mm/yr are amongst the highest ever recorded or estimated. The high denudation rates in the Himalayan mountains indicate a very dynamic environment in geological terms [33].

Because of this Himalayan rivers bring down enormous quantities of sediment. Ganga carries 340 mt of sediments per year, Brahmaputra 650 mt and Indus 320 mt. [14]. Ganga and Brahmaputra together have sediment yields higher than any other river in the world except for Hwang-Ho. Only one large river in Africa — the Orange — has a sediment yield exceeding one t/ha and most north and south American rivers have yields around one t ha. But both Ganga and Brahmaputra have annual sediment yields exceeding 10 t/ha[66]. Some of their tributaries, have even greater sediment yields, like the Kosi and the Teesta (see table 21).

According to one estimate, the world's oceans receive about 8,000 million tonnes of sediments per year, of which over a quarter comes from the Ganga and Brahmaputra alone[66]. Though undoubtedly high, data on sediment yields of these rivers is extremely unreliable. Estimates of annual sediment transport by the Ganga and Brahmaputra together

Table 21

Sediment yields of Himalayan rivers

River	Sediment yield (cum/ha/yr)
Ganga (at Farakka)	4.33
Arun	11.91
Sun Kosi	27.30
Tamur	60.76
Kamla	28.72
Kosi	16.32
Ramganga	17.30
Brahmaputra (at Pandu)	7.81
Dihang	7.95
Teesta	98.40
Burhi Dihing	17.73
Lohit	34.20
Manas	7.85
Subansiri	10.91
Pagladiya	31.40
Indus	
Chenab	25.20
Sutlej	6.00
Beas	15.10

Source : 14,85

Table 22

Sediment load of top five rivers of the world

River	Location	Sediment load: John Holeman 1968 Source 86 (mt)	James Coleman 1969 Source 87 (mt)	Narayana and Babu 1983 Source 68 (mt)
Yellow	China	2080	-	-
Ganga	India/Bangladesh	1600	479	586
Brahmaputra	China/India/Bangladesh	800	608	470
Yangtze	China	550	-	-
Indus	India/Pakistan	480	-	106

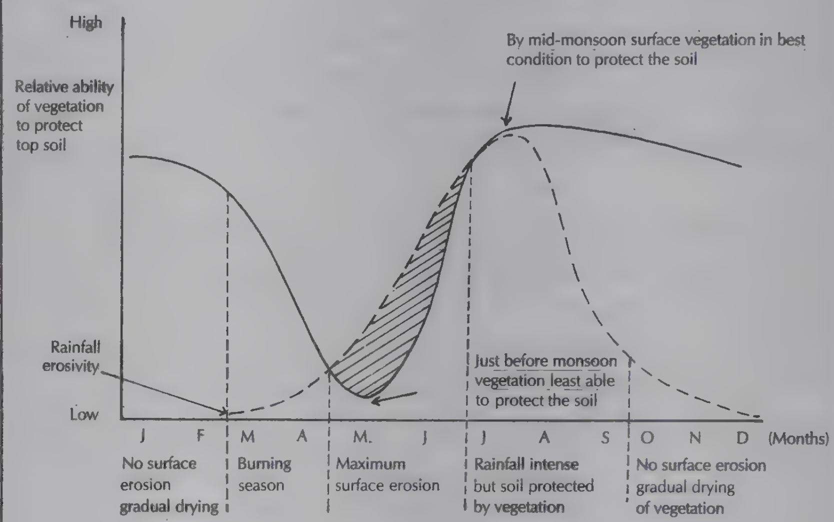
Source : 68,86,87

range from about 1,000 mt to over 2,000 mt (see table 22). Often, measurements are made during dry seasons, when loads are low, while rainy season floods carry maximum loads but are extremely dangerous to measure. Moreover, the load measured is often only the suspended load. The bedload is now regarded to have been grossly underestimated throughout the Indian and Nepal Himalaya. Sand waves and dunes on the Brahmaputra bed in Assam reach heights of 15 m and lengths of 200 m to 900 m, and can migrate downstream by as much as 600 m per day. The bed load alone can amount to 10-20 million tonnes (mt) a day — almost equal to the suspended load during a flood [66]. Not surprisingly, sedimentation rates of reservoirs built in the Himalaya have invariably been higher than those predicted prior to construction.

Yet, scientists are also finding that the Himalayan mountains are remarkably stable. For instance, the mapping of mountain hazards in certain parts of the Greater Himalaya in Nepal has led to the conclusion that, with the exception of areas characterised by severe tectonic disturbance together with susceptible rocks, the high angle slopes are remarkably stable[33]. The common assumption that soil erosion in the Greater Himalaya must be very high because of the high slopes is not entirely true.

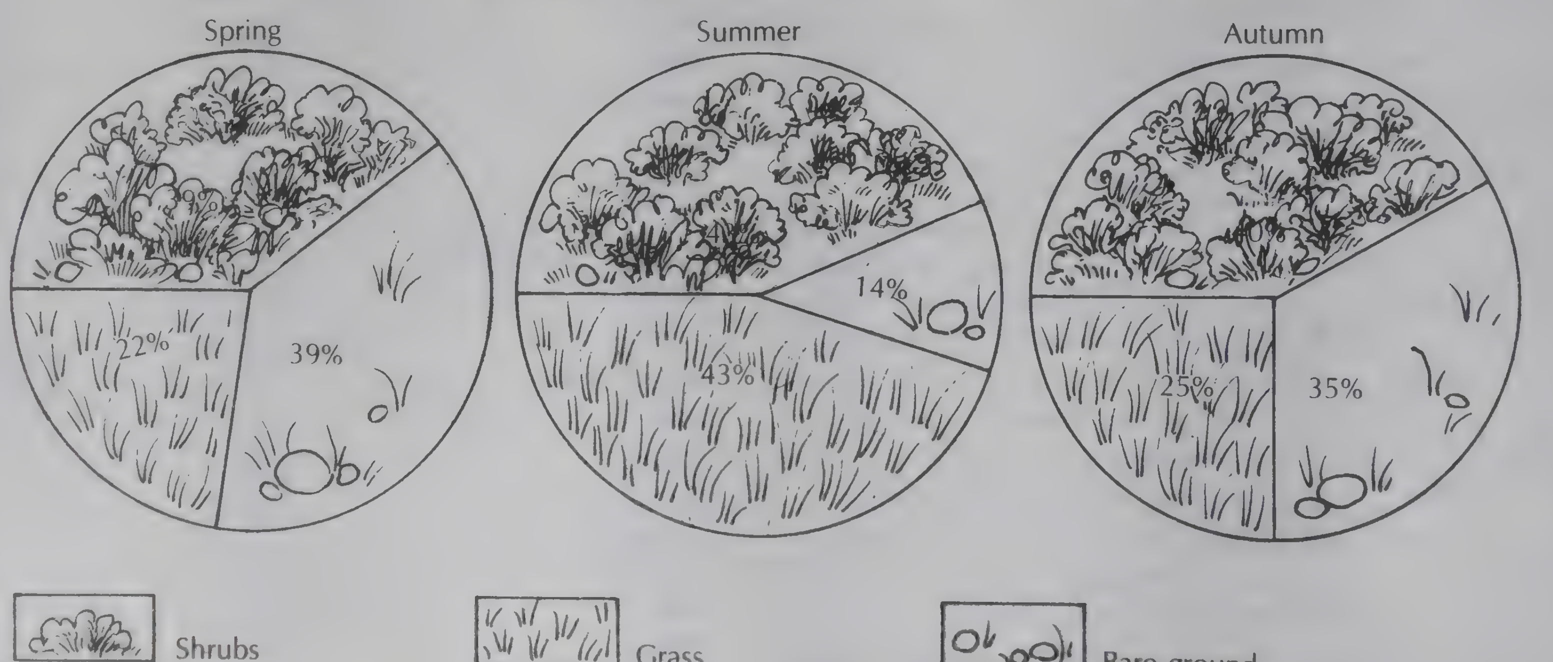
One study even shows that surface erosion rates are usually very small, except in overgrazed pastures, with sandy soils. The low surface erosion can be explained by the rapid spread of vegetation with the onset of the monsoon. Many areas, which had less than 50 per cent grass

Surface vegetation and soil protection



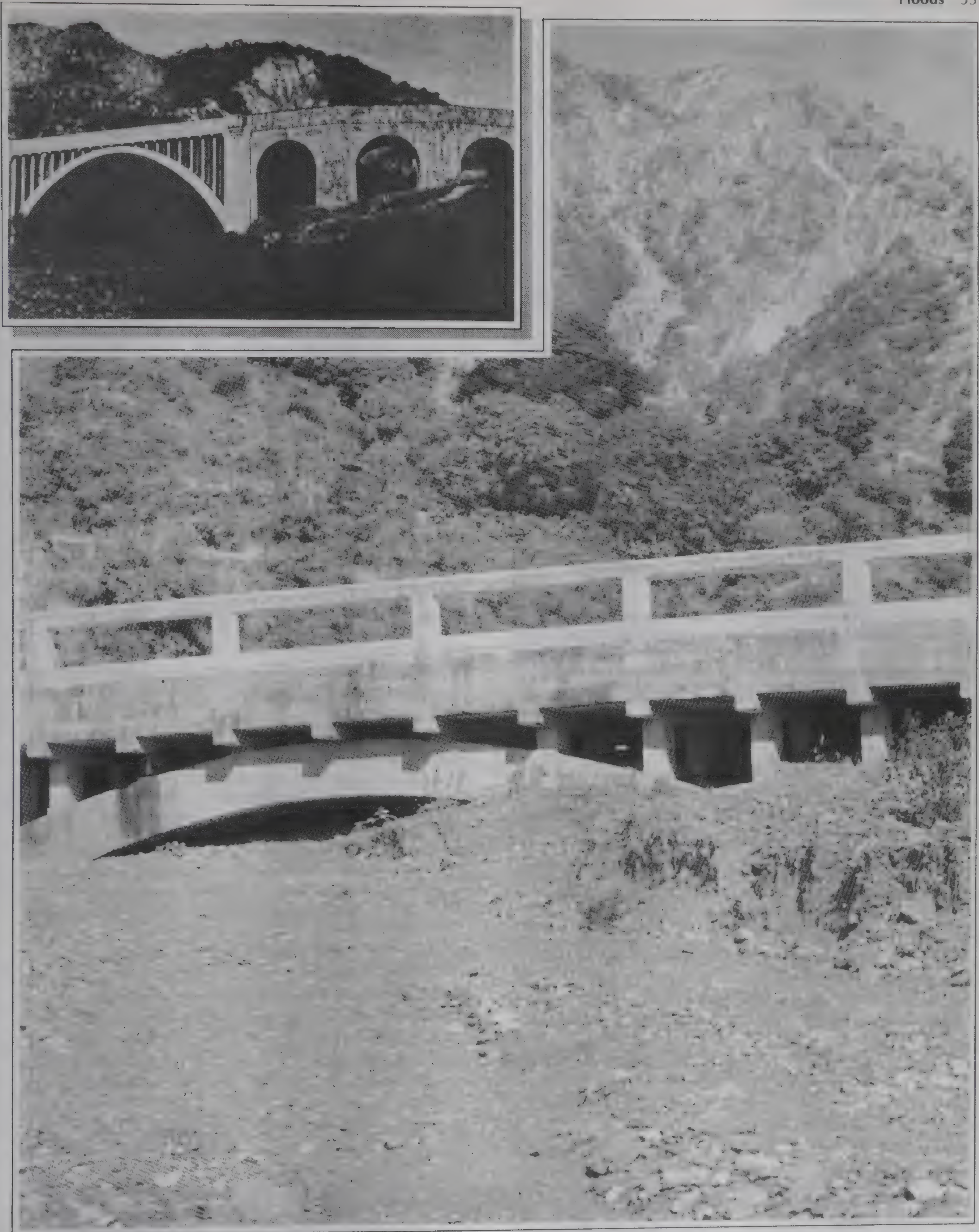
Source : 60

Spread of grass cover during monsoons



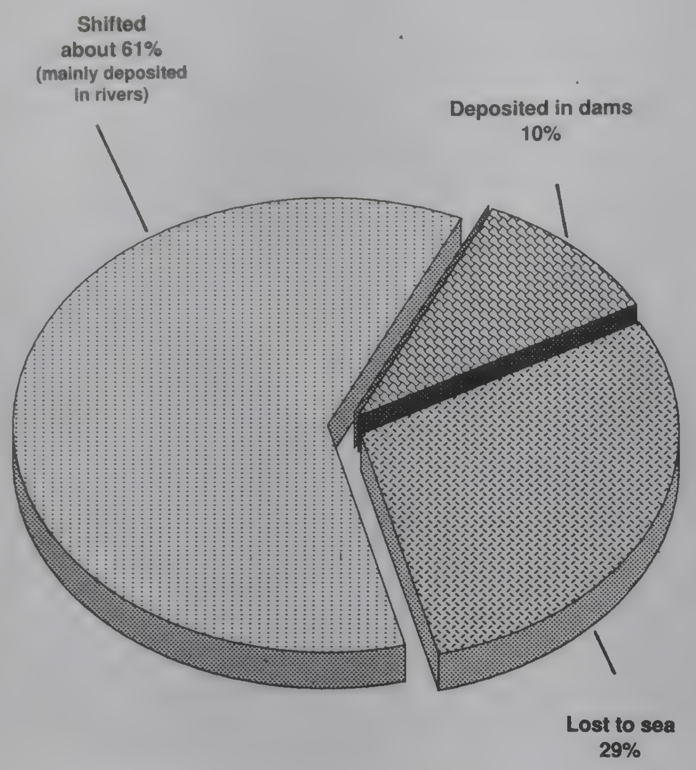
Source : 33

Many areas with little grass cover during the summer became well covered with the premonsoon showers. This rapid growth of grass cover probably accounts for the low rate of surface erosion in the Himalaya.



RISING RUBBLE : The Kaulagarh Nullah near Mussoorie has recieved so much silt and rubble in recent years that the bridge across it is now nearly covered. The level of the nullah bed has risen by 20 m in 70 years. (CSWCRTI).

India's annual soil loss



Source : 69

About 5,334 million tonnes of soil are eroded every year in India. Some of it gets deposited in dams reducing their storage capacity and a large portion is carried around by rivers and settles in their beds. The Ganga and Brahmaputra alone account for a quarter of the sediment the world's oceans receive.

cover in the premonsoon season became well covered with the premonsoon showers and light rains early in the summer monsoon season[33]. Dry season trekkers would, of course, be alarmed by the low ground cover then and anticipate severe erosion during the monsoon. Studies carried out by Indian researchers in the lesser Himalaya also show very low rates of surface erosion — 0.014 to 0.081 t/ha — even including deforested sites [63]. Studies conducted by Central Soil and Water Conservation and Research Training Institute (CSWCRTI) in the Siwalik hills do show high rates of erosion, especially in cases of extreme deforestation and heavy human disturbance. But they also show that a grass cover or even a natural fallow with grasses and shrubs greatly reduce runoff and soil loss, almost to negligible levels (see table 23)[67].

In fact, a study conducted by the CSWCRTI, shows that the total quantity of soil eroded from the Himalayan mountains is quite small in a nationwide perspective. The institute estimates that the total quantity of soil eroded every year is 5,334 mt — an average soil erosion rate of 16.4 t/ha — of which Himalayan mountains contribute only about 218 mt, which comes to an average soil erosion rate of only about 4 t/ha (see table 24).

The Ganga, Brahmaputra and Indus account for over half of the silt load of all Indian rivers, But not even a fifth of their silt load comes from Himalayan mountains. The black soil region of central India alone generates an estimated 3,376mt of eroded soil — an average rate of about 50 t/ha[68].

The landslides

Many scientists therefore argue that mass movements like landslides and catastrophic events like jokulhlaups may be more important causes of soil loss in the Himalayan

Table 23

Effect of grasses on runoff and soil loss

Experiment	Runoff as % of rainfall	Soil loss (t/ha/yr)
Experiment 1		
Bare fallow	71.1	42.4
Bare and ploughed fallow	59.6	155.9
Natural grass	21.2	1.0
Grass cover	27.1	2.1
Experiment 2		
Grass cover *(Pueraria hirsuta)*	0.6	0.1
Grass cover *(Dichanthium annulatum)*	0.7	..0.2
Grass cover *(Chrysopogon fulvus)*	0.9	0.3
Grass cover *(Eulaliopsis binata)*	1.9	0.3

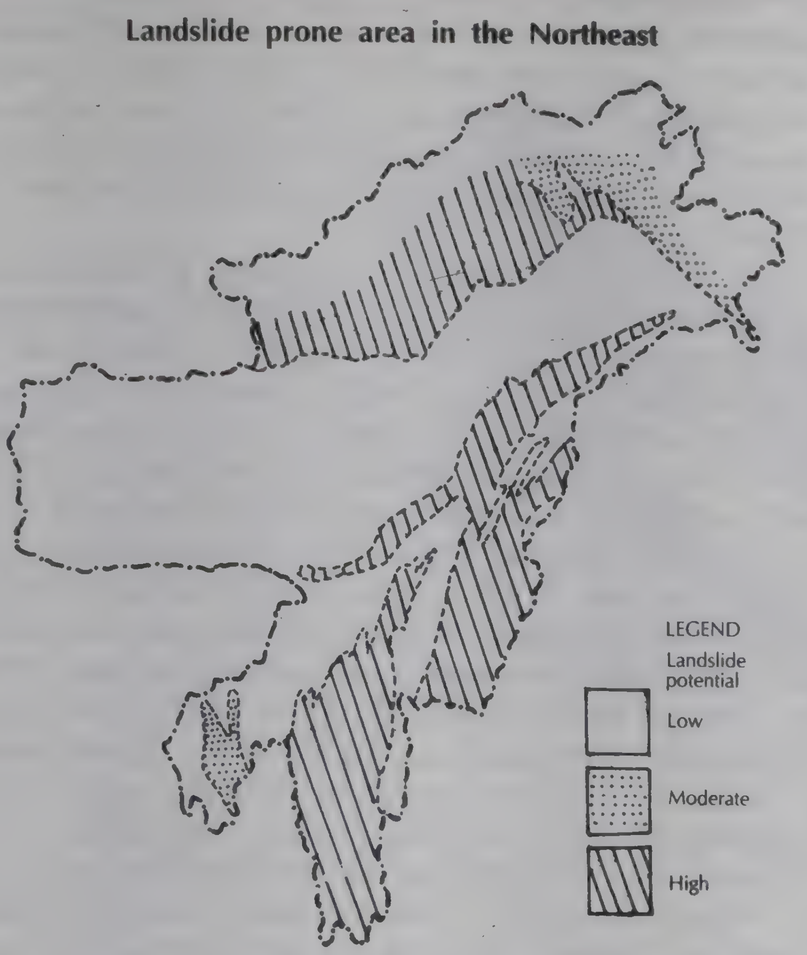
Source: 67

Table 24

Annual soil loss estimated in the Himalaya

Region	Proportion of area (%)	Soil loss per unit area (t/ha)	Total annual soil loss (mt)
North Himalaya (Snow clad region)	100	neg	-
North Himalaya (Alpine grass and meadow region)	100	0.16	1.6
North Himalaya (Forest region)	25	nil	-
	75	2.87	28.4
Northeasten Himalaya (Alpine grass and meadow region)	25	nil	-
	75	0.50	0.6
Northeastern forest region	25	nil	-
	50	2.87	23.2
	25	40.95	163.8
Total Himalaya		4.16	217.6
India	16.35	5333.7	

Source: 68



Source : 69

The Northeast is very landslide prone because of weak geology, intense rainstorms and earthquakes. Large parts of Arunachal Pradesh, Nagaland, Manipur and Mizoram suffer from severe landslide problems.

mountains than surface erosion. For that reason, annual averages are relatively meaningless in the Himalayan context. The silt tends to move more in explosive waves whenever there is a catastrophic event than by averages. Landslides are the main source of soil loss in the central Himalaya, according to a study by Kumaon university. They account for the bulk of the sediment load of the rivers. Geologist K S Valdiya points out that massive landslide events like those of July 1970 in the Alaknanda valley and of August 1978 in the Bhagirathi valley can bring frighteningly high quantities of sediment in a very short period and upset all averages of data collected over previous years[14].

Another expert claims that catastrophic events in the Teesta valley, increase average denudation rates several times[33]. Landslides are ubiquitous all over the Himalayan ranges. According to R K Bhandari, a landslide expert, Himalayan landslides continue to throw a challenge of such a magnitude that all tools and techniques of analysis and control in the armoury of a landslide specialist pale into insignificance[44].

Landslides in the western Himalaya have affected vital roads, river valley projects and urban and rural settlements[22]. Landslides are common also in the Northeast. The Geological Survey of India has prepared a map of the Northeast to depict the distribution and intensity of slide processes. The map shows that large parts of Arunachal Pradesh, Nagaland, Manipur and Mizoram suffer from severe susceptibility[69].

Table 25

Landside dams on Himalayan rivers

YEAR	EVENT
1841	A huge rockmass from Nanga Parbat fell into the Indus and formed a lake 64 km long. Few months later the dam burst.
1846	Due to massive lanslide, the flow of the river Kali stopped for several hours.
1857	A massive landslide blocked the Nandakini river for three days.
1868	A landslide lake near Jhinjhee in the Birahiganga valley burst and killed 73 persons at Chamoli.
1893	Gohana slide hurtled down several thousand metres into the Birahiganga in October 1893 and filled up the river bed to a height of 350 m. The lake formed was 5 km long and 2km wide. On August 24 1894, a part of the dam toppled raising the water level by 50 m at Srinagar. The town of Srinagar was completely destroyed. Two days later, the level of the river Ganga rose by 4 m at Hardwar.
1950	Widespread landslides blocked the Brahmaputra and its tributaries following a major earthquake.
1957	A long lake was formed by the landslide debris brought by the Dronagirinala near Bhaphund.
1968	Floods in Rishiganga created a 40 m high blockade near Reni village. The lake silted up by May 1970 and eventually the blockade was breached in the July 1970 floods.
	A landslide dam at Labubensi in Nepal on the Burhi Gandaki river broke and caused disastrous flooding downstream.
	Widespread landslides on the Teesta caused death and devastation all over Darjeeling and Jalpaiguri.
1970	The narrow gorge of the Patalganga got chocked and more than a 60 m high reservoir was built up. The bursting of this dam resulted in a flood pulse in the Alaknanda valley which triggered off many more landslides. The village of Belakuchi was washed away.
	Floods in the Birahiganga triggered several landslides causing a major blockade of river with a 10-12 m afflux. The Gohana Tal was completely silted up.
1976	Nandakini river blocked for hours due to massive landslides.
1978	Kanodia Gad, a petty tributary joining the Bhagirathi river upstream of Uttarkashi, spread a debris cone across the main river impounding it to a height of 30 m. Breaching of the landslide caused havoc due to flash floods. A 1.5 km long and 20 m deep lake was left behind by the landslide dam.
1979	River Saraswati was blocked by an avalanche near Mana village.The water level rose up by 2 m.
1981	River Tinnau in Palpa district, Nepal was blocked by a landslide during prolonged rains in September 1981. The breaking of the dam killed 200 people downstream in the Terai region.

Source : 27,60,77.

Numerous factors inherent in Himalayan ecology — weak geology, intense rainstorms and earthquakes — make these mountains prone to landslides. It is intense rainfall that usually acts as the trigger. Heavy or prolonged rains often reactivate old landslides[27]. A study in a watershed in Nepal found that the maximum number of landslides occur during the monsoon. As there were no landslides at other times, seismic shocks by themselves cannot be the main cause in regions away from the epicentre[9].

As water generally flows down Himalayan slopes in the form of subsurface flows, and because the soil mantle is usually shallow and rests on soft, fast weathering rock, Himalayan slopes are inherently susceptible to landslides63.

Experts of the Central Road Research Institute claim that experience in the Himalaya has taught them that a carefully designed drainage system has invariably proved to be the most effective measure in preventing or correcting a landslide.

Apart from bringing down large quantities of sediments, landslides become a major cause of devastating floods because they block the narrow gorges. Maps and aerial photos can be used to locate sites where such natural dams can form. They are normally marked by a sudden change in the gradient of a tributary stream, constriction at the point of confluence and weak geological conditions in the catchment of the tributary. The formation of landslide dams is common in the Himalaya (see table 25).

The high sediment flows resulting from landslides can be totally eclipsed by jokulhlaups in the greater Himalaya which are now being recognised as of considerable importance for sediment transfer to the Ganga plains over longer geological periods. The 1985 moraine dam outburst in Nepal removed about 0.9 mcum of material most of which was redeposited within about 25 km. Subsequent rainstorms will carry away the coarse material further downstream. According to geographers Jack Ives and Bruno Messerli, the enormous silt brought down by the Kosi could be the result of periodic jokulhlaups in its headstreams like Dudh Kosi, Sun Kosi and Arun[33].

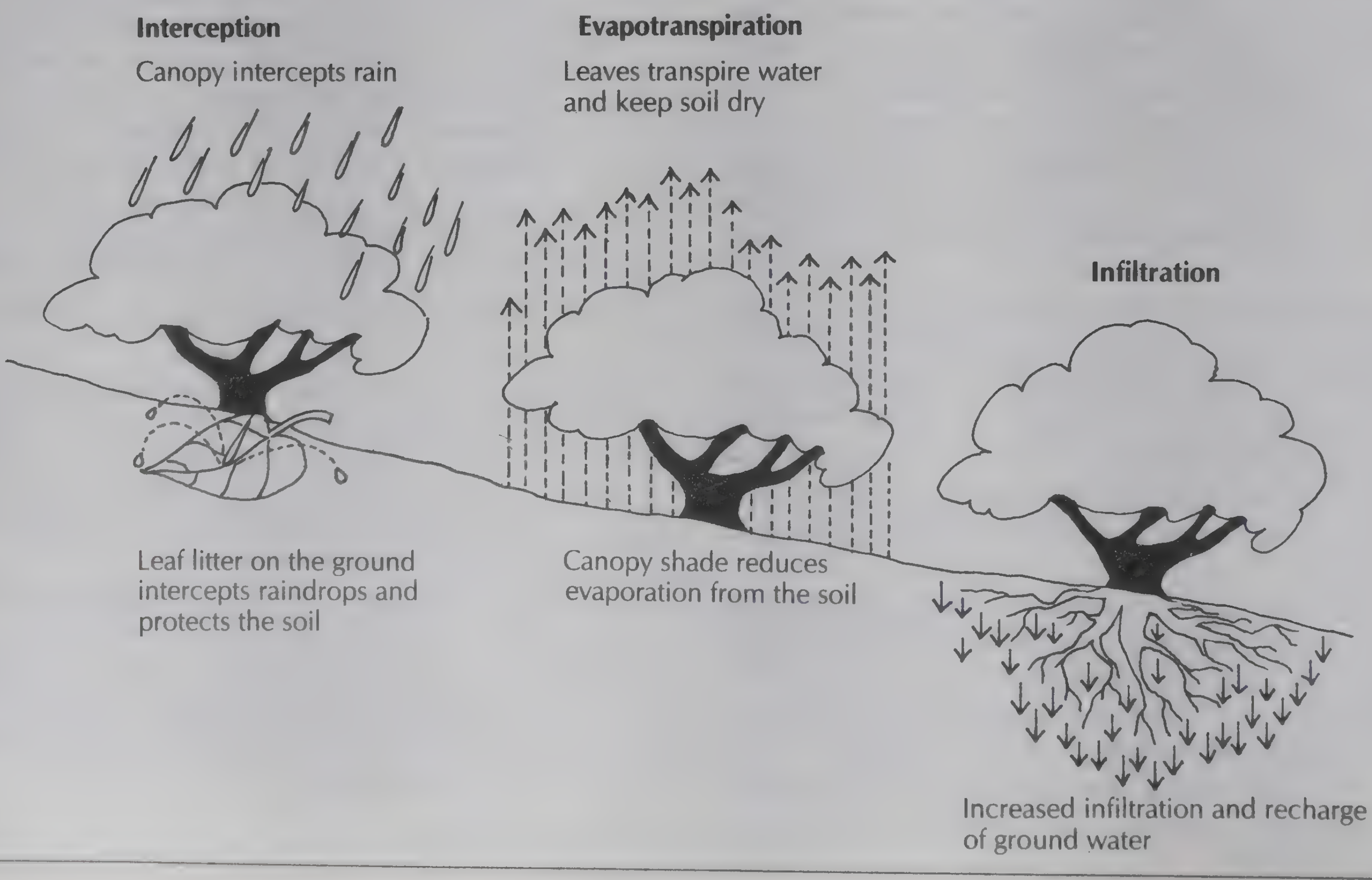
John F Shroder Jr , professor of geology at the university of Nebraska, claims that all the 17 known major historic floods on the Indus were the result of breaking ice or landslide dams. In January 1841, an earthquake triggered a massive landslide from the Hattu Pir spur of the Nanga Parbat mountain into the Indus. The landslide was 1.9 km high vertically and covered a horizontal distance of about four km. The resulting 150 m deep reservoir on the Indus backed up water 30 km upstream to the confluence of the Hunza and Gilgit rivers. As the impounded Indus rose, other rock slopes failed and made giant waves in the lake. When the landslide dam finally failed in June 1841, it sent a wall of water, mud and rocks roaring out of the Tarbela gorge.

"In the course of our recent search for the original 1841 rockslide dam, we discovered many large dams," says Shroder Jr Another major landslide blocked the Hunza river in 1858 at Pungurh. When the dam broke, it caused significant flooding downstream and large failures have continued on both sides of the valley ever since[47].

IMPACT OF HUMAN INTERVENTION

Evidence clearly indicates that the Himalaya-Brahmaputra-Ganga-Indus system is one of the world's most dynamic mountain building and sediment transfer systems[33]. The

Effect of trees on rainfall



The Himalaya ranges and rivers

ongoing processes have combined to create a high mountain landscape of utmost complexity.

Over this landscape, human activity has wrought enormous ecological changes over the last few centuries. Large areas have been deforested, agriculture has expanded, vast networks of roads have been built and numerous dams have been constructed or are under consideration. Many environmentalists believe that this is increasing floods downstream.

But how true are these beliefs?

Impact of deforestation

The environmentalists' theory is that forests act like a sponge, absorbing large quantities of water during the wet season and gradually releasing it. Forests also reduce erosion and landslides. Therefore, if the Himalayan slopes can be afforested, the destructive flood-drought cycle that has been unleashed can be arrested.

Impact on water flows

Forests influence the hydrological cycle by:

i) intercepting rainfall and allowing it to evaporate back to the air;
ii) transpiring large quantities of soil moisture and keeping the soil dry;
iii) creating soil conditions that allow greater infiltration of water into the ground; and,
iv) reducing peak water flows during a rainstorm.

Interception

Rainfall on a forest canopy is caught by leaves and branches. It evaporates as it moves towards the forest floor. Interception loss — the amount of rain water intercepted by living and dead plant material and evaporated back to the atmosphere — is influenced by wind, rainfall intensity and type and density of vegetation. Very light rainfall can be totally intercepted while heavy rainfall will rapidly saturate the forest canopy and most of it will get transmitted to the forest floor. Experiments show that interception loss is governed more by rain intensity than tree species (see table 26).

In a forest of sal (*shorea robusta*) interception loss was 37.3 per cent of rainfall during a light shower (4.2 mm), and 4.1 per cent during a heavy shower (140.3 mm). As the quantity of intercepted water is small during a heavy rainstorm, interception by forests will have little effect upon major floods[70].

Table 26

Rainfall interception by an Oak forest in Dehra Dun

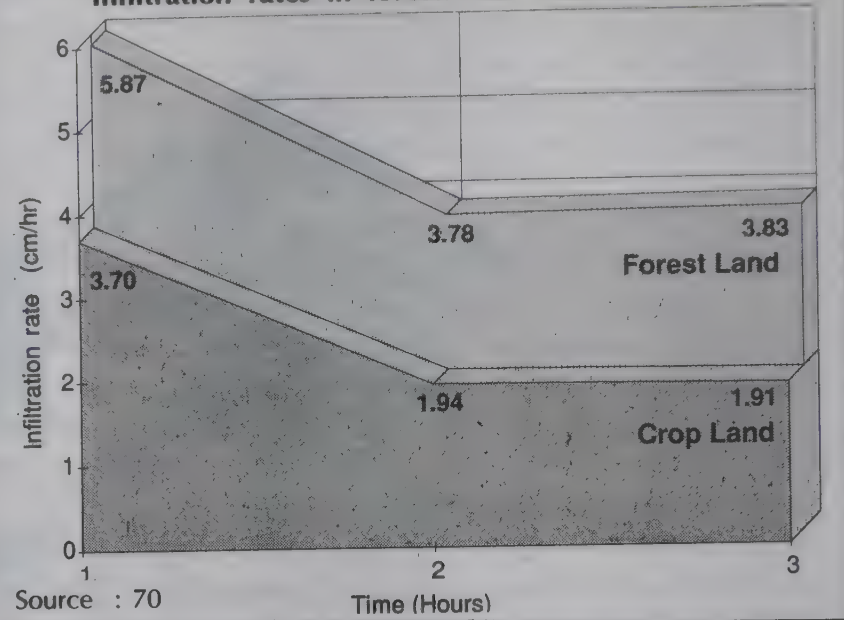
Rainfall (mm/day)		Interception (as % of rainfall)
0-10 mm	Low	74.1
10-50 mm	Medium	37.1
50-100 mm	High	17.3
Over 100 mm	Very High	6.9

Source : 88

Evapotranspiration

The combined loss of water by evaporation from the soil and transpiration through plant leaves is termed evapotranspiration. While forests will normally reduce evaporation from the soil, they will increase transpiration. Evaporation from land covered by a forest usually ranges from 10 per cent to 80 per cent of that from bare soil. But in most cases transpiration loss from a good forest more than offsets the reduction in evaporation.

Transpiration depends on various environmental factors and trees species. Shallow rooting trees such as spruce and poplar have only 1.5-2 m deep roots, whereas deep rooting trees like oak and pine reach 4-6 m depths. Deep rooting trees transpire large quantities of water, sometimes as much as the entire amount of rain that falls over a year. Transpiration rates of well stocked forest lands can be over twice that of crop lands and five times that of meadows. Studies on evapotranspiration in different types of forests have not been undertaken in India. But an evapotranspiration estimate for the Damodar catchment, which has 1.87 mha of dry deciduous forests, puts it at 560 mm/yr — about half the annual precipitation in the area[70]. In other words, trees almost act like pumps and, hence, afforested catchments normally have reduced stream flows compared to deforested ones. Experiments on small watersheds across the world have shown that deforestation results in increased annual water yield — usually between 20 per cent to 40 per cent[70].

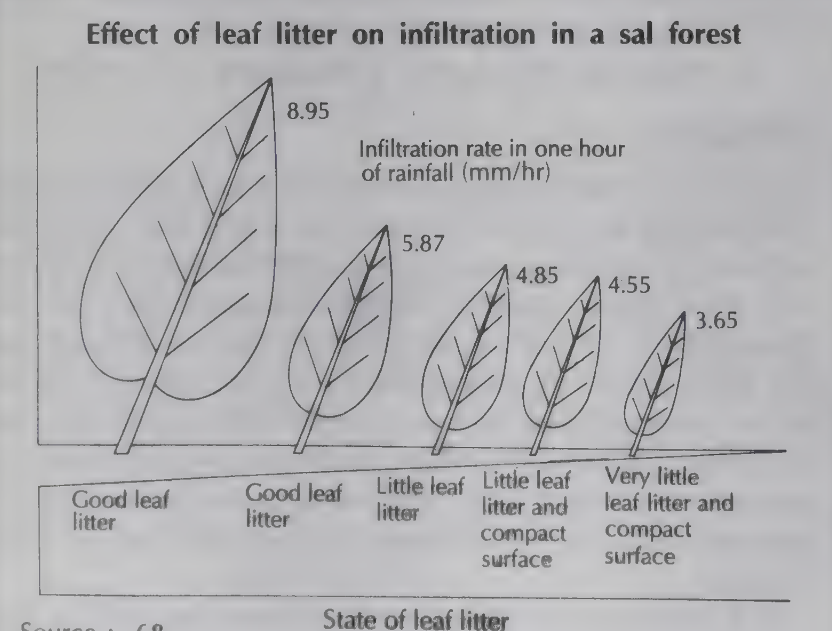


Source : 70

Infiltration rates under forest lands are higher than under agricultural lands in the first few hours of rain. But they drop rapidly if rain continues.

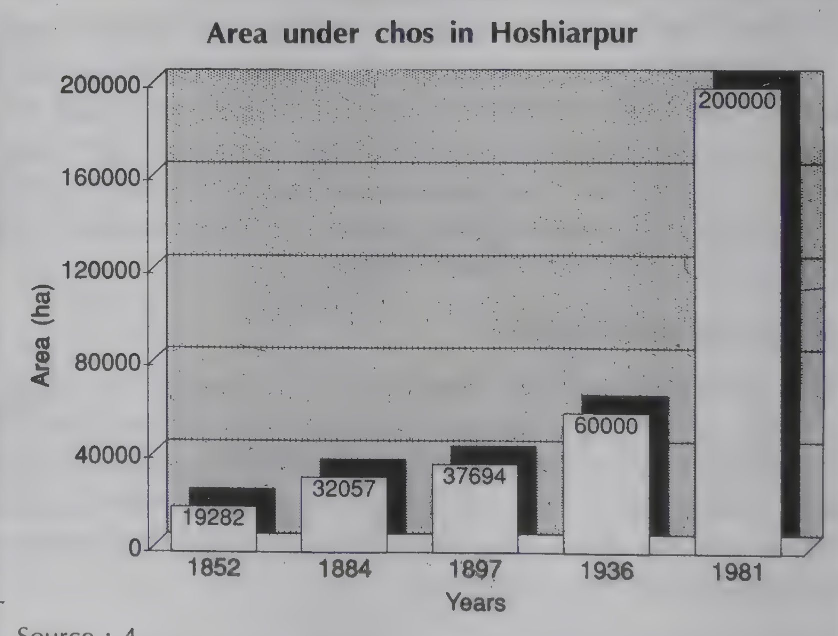
Infiltration

Infiltration is the process by which rain water enters the soil. Leaf litter and vegetation greatly increase the organic matter content of the soil and improve its structure increasing its infiltration capacity. Infiltration rates under forest lands are higher than under cultivated lands in the first few hours of rain. But they drop rapidly if rain continues. Therefore, infiltration rates will be low during intense and prolonged rain, and afforestation will not make much difference. Infiltration rates also depend on the nature of the soil. For instance, infiltration rates in sandy soils are invariably high,



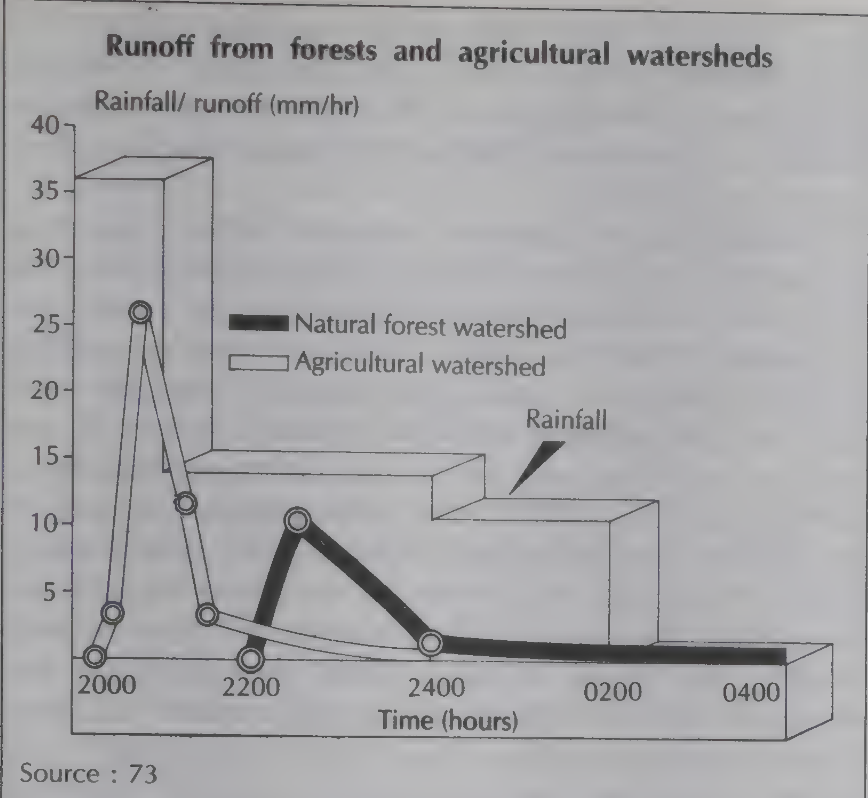
Source : 68

Forests provide a layer of decaying organic matter (leaf litter). Associated with tree roots this makes the soil more conducive to infiltration. But the rate of infiltration falls once the soil is no longer dry. Therefore, forests fail to have a great effect on water flow in case of prolonged and intense rains.



Source : 4

The chos are streams originating in the Siwaliks, which carry immense amounts of silt. The river beds rapidly become wide and shallow. Following extensive deforestation, the chos, once perennial, have become seasonal. The widening of their beds, has increased the area under chos from 19,282 ha to 0.2 mha in Hoshiarpur district.



Forests reduce peak runoff from small watersheds during high intensity storms by 10 to 20 per cent through interception and infiltration. Major floods, however, occur during intense and prolonged rainstorms when the watershed is saturated and infiltration and interception effects are minimised.

whether they have a forest or not[70]. The high rate of evapotranspiration by forests increases storage space for moisture in the soil. Tree roots leave the soil in a more receptive condition to accept water during rainfall. Infiltration can be total in a forest area when the soil is dry and deep and only a short, light rain occurs. But it is small, when there is heavy and prolonged rainfall, especially on wet, shallow soils[71].

The observations

The overall impact of a forest on the hydrology of a particular site, therefore, depends on the interaction of a number of factors — the type, number and density of trees, the state of leaf litter, soil characteristics, intensity and duration of rain, and various environmental factors.

Dry season flows of Himalayan rivers have decreased after deforestation. C K Sharma of the Water and Energy Commission of Nepal points out that "most Terai rivers, which previously contained water during the lean season, are now found to be dry during winter. Such effects are also seen in the rivers of the Middle Hills of Nepal. The low flow discharge of the Tamur river has decreased considerably in the last few years and this is mainly due to large scale deforestation in the upper valley" [59]. Indian observers claim that the chos of the Punjab Siwalik, once perennial streams, have become seasonal ones. Chos today seem to carry more mud and silt than water. They disappear after about 20-25 km from the foothills. Their beds silt up rapidly. The 55 km Swan river in Himachal Pradesh now has a width of two km and its muddy torrent cuts into hills, washing away fields. Cho beds which covered only 19,282 ha in 1852 in Hoshiarpur district of Punjab, now cover over 0.2 mha[42].

Unfortunately, quantitative data about changes in streamflows is not available and such evidence is usually anecdotal. Studies carried out by the CSWCRTI on small watersheds confirm that afforestation reduces total volume and peak rate of surface runoff; and streamflows last for a longer period after the cessation of the rains.

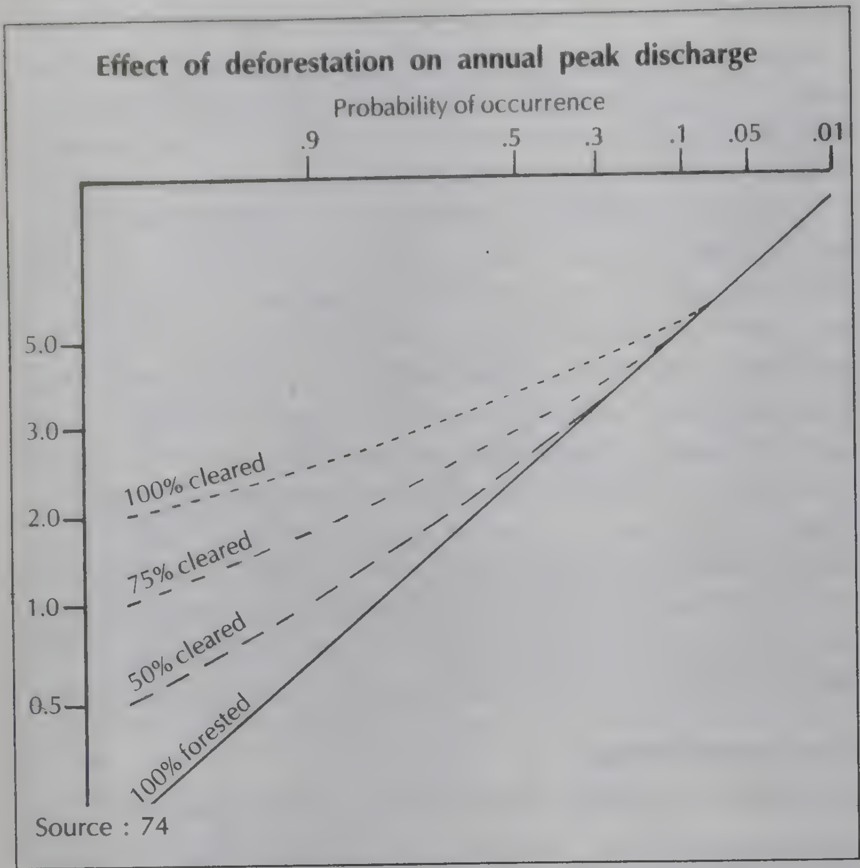
A study by CSWCRTI in the Dehra Dun region found that, the volume of runoff went down by 28 per cent after afforestation and the peak rate of runoff was reduced by 73 per cent[72]. Another study compared an agricultural watershed with a forest watershed subject to open grazing. Even this experiment showed that the volume of runoff was 15 per cent lower in the latter and the peak runoff rate 72 per cent lower[73]. CSWCRTI's efforts to afforest and treat the eroded catchment of the Nalota Nala near Dehra Dun, which used to dry up soon after the monsoon, has resulted in streamflows for longer periods. In other words, a sponge effect does come into operation with afforestation which reduces peak runoff rates and prolongs dry season streamflows.

The contradictions

Yet several experts do not accept the contention that afforestation of the Himalaya will prevent major floods in the Indo-Gangetic plains. Major floods occur during intense and prolonged rainstorms, when the watershed gets saturated and both interception and infiltration effects are minimised[71]. Often major floods occur late in the monsoon season when watersheds are near saturation. No data exists to assess the impact of forests under such conditions compared to the impact of natural factors such as the intensity of the rain and size, shape and geology of the river basin, and human induced ecological changes in the flood plains themselves. Moreover, most experiments (like the one cited above) have been conducted on small watersheds while several experts argue that hydrological responses of large watersheds can be different. Subsurface flows in large watersheds may be substantially different than in small watersheds. Data collected from experiments on the latter possibly explain local effects better than large scale regional effects[70].

As Lawrence Hamilton, a watershed expert at the East West Centre in Hawaii, puts it, a good forest cover in the Himalaya constitutes the safest land use to reduce floods but if deforestation is replaced by terraced agriculture and well managed grasslands, there should be little effect on downstream floods. Only if deforestation results in an extremely abusive land use in the form of intensely overgrazed grasslands which lead to heavily compacted surface soils, eroded and gullied terraces, and roads and channels which speed water runoff on a sufficiently extensive scale across the river basin, downstream floods could get aggravated[71].

Undoubtedly, forests are being replaced by an abusive land use in many places in the Himalaya. But again there is no quantitative data to show how extensive is this adverse land use and to what extent it is affecting hydrological conditions. As yet studies carried out both in India and Nepal show that infiltration rates even on deforested sites, including those which have been converted into heavily grazed and trampled grasslands, are sufficiently high.



The above chart, though not prepared specifically for Himalayan conditions, shows that major floods expected to occur once in 15-20 years will not be affected whether the watershed has a forest cover or not. But low floods can occur much more frequently with deforestation. Human society will have to learn to live with major floods.

Afforestation will, therefore, have a limited impact in terms of changing hydrological conditions[63, 64].

Unfortunately, such studies are very few. More studies are needed in different parts of the Himalaya. But existing studies do caution us towards beliefs that Himalayan deforestation has greatly exacerbated floods over and above natural causes.

An FAO publication summarises the impact of afforestation on floods with the help of a graph that presents the probability of a flood of a certain size occurring under different levels of forest cover in the watershed. The chart, though not prepared specifically for Himalayan conditions, shows that major floods expected to occur once in 15-20 years will not be affected whether the watershed has a forest cover or not. But the peak discharge of floods that occur more frequently (say, once in two years) could more than double. In other words, forests can moderate minor and medium floods. But human society will have to learn to live with the major floods[74].

Impact on soil erosion

Will afforestation reduce soil erosion and arrest the rapid silting up of river beds in the Indo-Gangetic plains? Forests have a significant influence on surface erosion and sedimentation of rivers. The existence of a forest canopy and, equally important, litter on the forest floor breaks the impact of rain drops on the soil. Moreover tree roots and increased organic matter in forest soils impart stability to them.

CSWCRTI studies have shown increased rates of surface erosion after deforestation. In some cases, they have reported rates as high as 80-156 t/ha/yr from small, deforested watersheds in the Chandigarh-Dehra Dun region[75]. But such cases seem to be restricted. CSWCRTI's other studies do not show such high rates of erosion everywhere in the Himalaya — between 2-5 t/ha[73]. Surface erosion in non-forested sites in the central Himalaya also appears to be low[63].

Watershed expert Lawrence Hamilton further argues that soil erosion rates found in small watersheds will not hold true for large watersheds. For instance, 90 per cent of the soil eroded in any year from a one ha watershed will be delivered outside the watershed by streams in that very year itself. But this sediment delivery ratio may be only 50 per cent for an 80 ha area and less than 30 per cent for a drainage area over 500 ha. For a catchment of the size of that of the Ganga, the sediment delivery ratio will probably be only 10 per cent. Most of the silt in the river comes from soil already deposited in the channels and from channel erosion. Even if all human activity was closed in the Himalaya and, as a result, all surface erosion hopefully came to a halt, the sediment load of the rivers in their lower reaches would show little change for a long time. The stores of eroded soil from the past would continue to feed the rivers. In other words, if afforestation was undertaken today, it might improve local conditions within a few years, but silt loads in the large streams will not decrease for decades[76].

Geographers Jack Ives and Bruno Messerli, in fact, argue that silt loads in major rivers may not decrease substantially at all. The increased erosion rates due to deforestation still do not match the levels of soil loss reached in the Himalaya because of mass movements like landslides and other catastrophic events. These processes are so predominant that human activity only has a limited impact in the dynamic environment of the Himalaya[33].

But if landslides are a major cause of soil loss in the Himalayan mountains, will afforestation reduce them? Scientific evidence shows that tree roots anchor the tree and the soil itself, greatly increasing the shear strength of the soil and preventing it from slipping down. When the soil is saturated with water during a heavy rainstorm, 80 per cent of the shear strength comes from tree roots. Loss of this shear strength by clearing forests can easily trigger shallow slides in areas prone to mass movements[71]. Afforestation of landslide prone areas in the Himalaya will definitely increase slope stability. Because of their heavy evapotranspiration rates, forests will keep the soil relatively dry and lower the water table. Soon after the 1968 rainstorm in the Teesta valley, a scientist found that landslide rates on non-forested tea slopes was 10 to 20 times higher than on forested slopes. Forests played the "most important" role in inhibiting shallow landslides but had no effect on "deep landslides"[77].

But several scientists also argue that forests cannot override the natural factors that cause landslides, especially in the Himalaya. A survey carried out in Kalimpong following the 1954 disastrous flood of north Bengal found that the primary cause of the landslides surveyed was susceptible geology. Human factors like deforestation, overgrazing and cultivation of slopes were subsidiary causes [77]. Another study of landslips along the Sun Kosi and Tamur rivers concludes that they have been mostly caused

by unfavourable geology and heavy rainstorm though deforestation did play a role[78]. An airborne reconnaissance of Nepal has concluded that 75 per cent of all landslides observed were caused by natural factors like geological structures and certain susceptible rock types[33].

Landslides tend to come in cycles. After a large landslide, there will be a period of relative stability. Then a large number of landslides will occur almost simultaneously on otherwise long undisturbed slopes. A triggering mechanism is invariably needed which can be a catastrophic rainstorm or a large earthquake. Such landslides will take place even on heavily forested slopes.

Large scale landsliding is followed by stability presumably because time is required for the bedrock to weather and a layer of topsoil to accumulate before the next major slope failure can take place. Climax soils can sometimes never develop on steep mountain slopes because the slopes are too unstable to allow a mature soil cover to evolve.

The results

Jack Ives and Bruno Messerli argue that forests will not be able to prevent major landslides, which occur more because of steep slopes and other natural factors like weak geology, seismicity and intense rainstorms. They can postpone the occurrence of major landslides but not stop them. Forests, as compared to grazed and bare slopes, will get destabilised less frequently and, therefore, small, shallow landslides will be prevented. But this will only facilitate the production of a deeper mantle — a thicker layer of top soil — and ensure a larger landslide in the future. Thus, the overall soil loss over a longer time scale will be the same with or without forests33. In other words, sooner or later major landslides will take place and Himalayan rivers will bring down enormous quantities of silt during intense rainstorms. Ganga and Brahmaputra will continue to carry a higher sediment load than most other major rivers worldwide and riverbeds will continue to silt up in the Indo-Gangetic plains.

According to geologist K S Valdiya, scientific investigations show that the current rate of erosion in Himalayan catchment areas is five times higher than that of the geological past. While the current denudation rate is about one mm/yr, over the last 40 million years it has only been 0.21 mm/yr 14. University of Guwahati geographer, D C Goswami, has also calculated that the present rates of denudation in the eastern Himalaya are far higher than the past rates of denudation. Goswami's studies show that about 20 per cent of the silt gets trapped in the Assam valley. The Brahmaputra valley in Assam is 5.62 mha in area and it has received a mass of sediments 200-300 m thick in the last two million years which gives an average rate of denudation of 0.03 mm/yr over this geological period. But this is only about one-fiftieth of the rate of denudation observed in the last 30 years[79].

Is it possible that current rates of erosion have increased because of deforestation and other human interventions ? Goswami argues that the present high rate of denudation is mainly because of ongoing uplift of the mountains. Though various estimates exist, there is a convergence around seven mm/yr. The current rates of denudation, howsoever high in comparison with other mountain systems, are lower than the rates of Himalayan uplift. According to American geographer John F Shroder Jr , modern rates of Himalayan uplift are, in general, about eight times greater than the average rate of denudation[47].

The higher a mountain rises, the steeper will be its slopes and the gradient of its valleys. This will result in greater surface erosion, mass movement and erosion of stream valleys. When these steep slopes have to face heavy rainstorms and earthquakes, erosion will intensify further. Therefore, scientists believe that there are major geological reasons to explain the increased erosion in the Himalayan mountains over geological history.

Table 27

Land Use in Himalaya (1985-86)

State/Region	Geographical area (mha)	Reporting area (mha)	Barren and uncultivable land (mha)	Culturable wastes, follows, pastures and land under tree crops (mha)	Net sown area (mha)	Forest area (mha)
Jammu and Kashmir	22.22[1]	4.51	0.57	0.46	0.73	2.75
Himachal Pradesh[2]	5.57	5.07	0.94	1.45	0.55	2.13
Uttar Pradesh hills[3]	5.11	5.30	0.32	0.86	0.69	3.44
Sikkim	0.71	0.71	0.27	0.09	0.10	0.26
Darjeeling hills	0.31	0.38	0.18	0.02	0.07	0.11
Arunachal Pradesh	8.37	5.49	0.06	0.16	0.12	5.15
	42.29	21.46 (100%)	2.34 (11%)	3.04 (14%)	2.26 (10%)	13.84 (65%)

Notes : [1]Includes area under occupation of China and Pakistan.
[2]Year of data not known.
[3]Data relates to 1986-87.

Source : 18, 89 for Uttar Pradesh hills, 89a for Darjeeling hills and 89c for Himachal Pradesh

STURDY SLOPES: Terrace farms contribute to the upkeep of slopes as farmers treat the land to prevent it from slumping and erosion. At times they resort to deintensification of land use to help terraced farms recuperate. (Anil Agarwal/CSE).

Impact of agricultural expansion

Expansion of agriculture in the hills has often been blamed for increased destabilisation of slopes, soil erosion and floods in the Indo-Gangetic plains. Geologist K S Valdiya, for instance, points out that pressure of the population has driven people to greater heights and steeper slopes, even above 2,000 m, to cultivate what were once forested tracts. Most of these villages and farms are located on the fan shaped debris of old landslides made of loose, fragmentary material and not very stable. Their cultivation has deprived these slopes of protective cover and increased erosion and waterlogging due to ingress of excess rainwater, especially in the absence of drains[14].

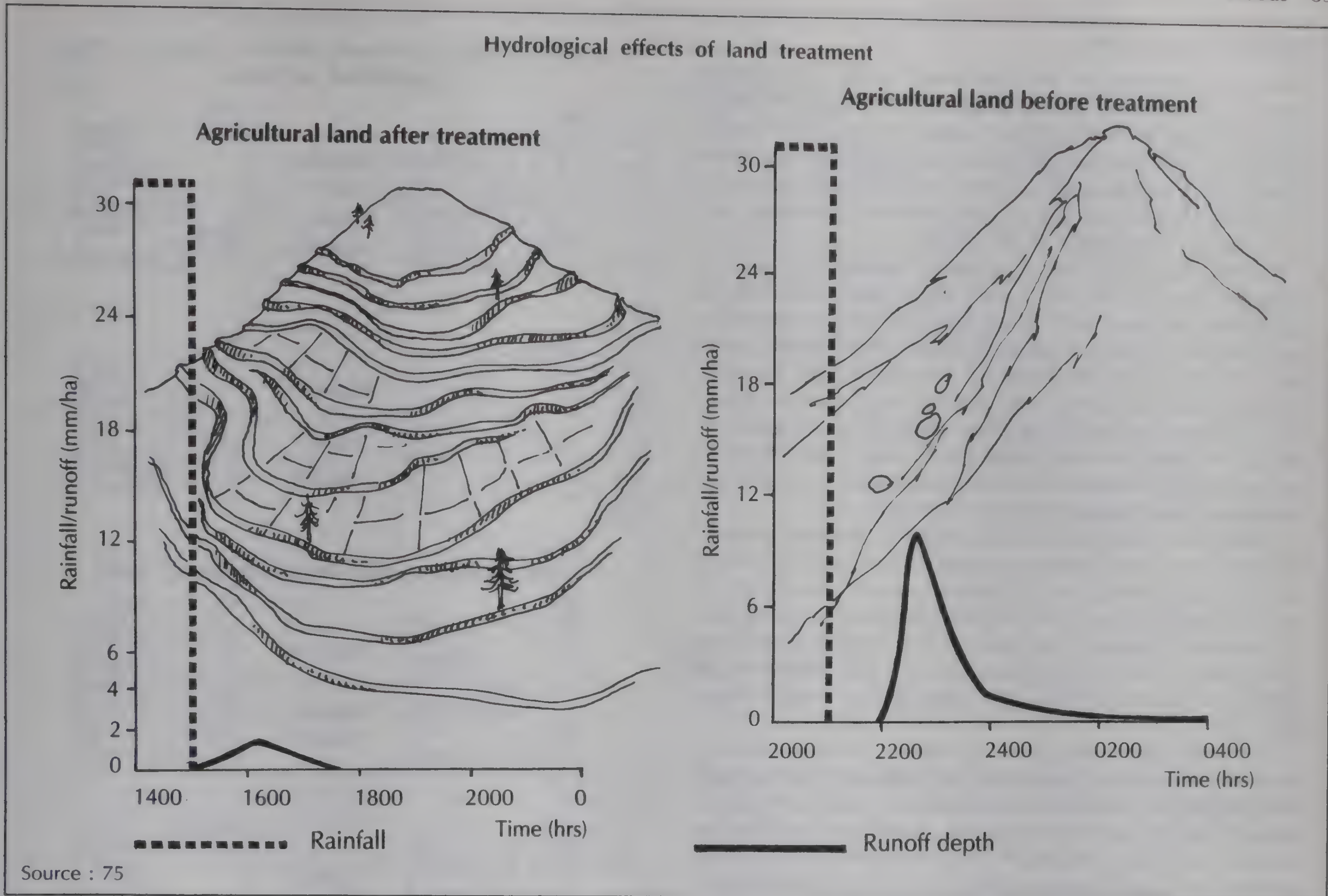
Popular perception also blames the poor farmers of the Himalaya for ecological destruction. Former Indian Prime Minister V P Singh in an interview to The Illustrated Weekly of India in 1989 said: "It is tragic to see the Himalaya now. I have flown over them many times in helicopters and seen the denudation of the forests. The mountains have been terraced by human hands, not bulldozers! You have to see it to believe it. The sheer human effort involved! The way they have gone about cutting down the trees and destroying the environment"[80].

But many scientists do not believe that agricultural farms have become a major source of erosion. A team recently studied two mountain streams in Nepal to assess the impact of human action on them. They found that the only impact on these streams was that their channel width in the uppermost eight km got constrained because of the construction of agricultural terraces, especially masonry walls. The stream, therefore, adjusted itself to cutting a deeper channel. No landscape modification because of the activities of the local subsistence farming community could be noticed further down.

Terrace farms

Jack Ives and Bruno Messerli are particularly critical of those who believe that terraced farming is leading to considerable erosion. They cite, for instance, a report by the Asian Development Bank (ADB) on Nepal, which states, "Terraces, especially on rainfed land, are often poorly constructed; they are outward rather than inward sloping and do not have a grassed bund on the edge". Ives and Messerli explain that bari or rainfed terraces in Nepal mostly support maize, millet, buckwheat and other crops. Constructed usually on the upper, steeper slopes with no irrigation facilities, they slope outward from the hillside so that crops are not damaged by waterlogging. Local farmers are aware that accumulation of water on terraces — that would result from inward sloping terraces — would exacerbate landslides. Furthermore, annual repair of terraces would increase. The summer monsoon rain is intended to run down the outward sloping terraces. Absence of a bund on the bari terraces (in contrast to the khet, or irrigated, terraces) is deliberate and ensures rainwater runoff.

Both bari and khet terraces are, for the most part, superbly engineered in Nepal, claim Ives and Messerli. "Admittedly, during heavy monsoon downpours, available human energy is concentrated on repairing damage to the khet and



Experiments conducted with small watersheds show that soil conservation measures can reduce water runoff rates from agricultural lands very substantially.

irrigation systems, and the bari terraces may have to be left to collapse; this is because the much higher yielding khet terraces, usually under paddy rice, are more vital to the survival of the subsistence family. Any apparent neglect of the terraces may be due to shortage of available labour rather than a reflection of the ignorance of the farmer", claim Ives and Messerli.

English mountaineer, H W Tilman, had observed in 1952: "Whether it takes place little by little or in one swift calamity, soil erosion is generally attributed to man's careless greed, his idleness or neglect. It would not, I think, be fair to blame the people of these valleys on the Himalayan fringe for the frequent landslides which occur here. In turning the steep slopes into fruitful fields they have neither been lazy nor neglectful." Ives and Messerli, in fact, argue that the subsistence farmers are highly knowledgeable and intelligent land managers with a wealth of accumulated, traditional wisdom. They recall the time when they were themselves not prepared to listen to them: "As somewhat representative of expatriate experts making short visits, we were able to observe the Middle Mountains of Nepal from brief road traverses out from Kathmandu in 1978 and 1979. Like many other visitors, we timed our presence to coincide with good weather — March, April and October — and were duly impressed with the large number of landslide scars and gullies that obviously had engulfed significant amounts of agricultural terrace land during the preceding summer monsoon periods. Since the project necessitated repeated visits of considerable duration to the field area throughout the agricultural cycle over a five year period, we were afforded the hitherto uncommon perspective of time. We were also able to develop communication with the subsistence farmers. This gave us a greater understanding of the landscape changes that have been occurring over several generations and an appreciation of local attitudes to dynamic slope processes and local responses to them."

Human contribution

It soon became apparent to them that many landslide scars are eventually reterraced and stabilised and irrigation systems are repaired. Thus, human beings contribute to the stabilising process of the slopes. In certain instances, local people perceived a landslide to be a beneficial occurrence because the more easily worked earth of the landslide scar actually facilitated terrace construction. Small landslides were sometimes deliberately triggered by water diversions in order to facilitate new terrace construction. The indigenous farmers have evolved an intricate set of coping strategies that include changes in land use to match changes in slope stability and subsequent reterracing of collapsed slopes. Agricultural deintensification often takes place as an adjustment to the threat of slope instability.

Between 1978 and 1987, Ives and Messerli made frequent visits to Kathmandu and took repeat photographs

STABILISING SLOPES

Himalayan farmers are no fools even though it is widely believed that their agricultural practices have made Himalayan slopes more prone to landslides. Studies carried out by Sumitra Gurung of the International Centre for Integrated Mountain Development in Kathmandu and several other researchers show that local peasants are rich in environmental knowledge and contribute to the stability of the slopes.

In the mountains, the population density per unit of cultivated land is, in many cases, even higher than that of Bangladesh. In recent years, there has been both an expansion and intensification of agriculture. Villagers in the Pokhara valley told US scientist Robert Schroeder, who studied the changing pattern of agriculture and pastoralism in Nepal, that when they were children, upland fields were either single cropped or double cropped with low management crops. Currently, they are being triple cropped with high management crops and are also being intercropped to maximise yields[1].

Himalayan farmers maintain a cropping diversity to minimise the risk of crop failure. Schroeder found that one village in 1979 was growing over 50 distinct varieties of wet rice. If dry rice and other crops were included, they were growing over 75 varieties. In addition, they grew a wide range of vegetables, chili, oilseeds, fruit and lentil species. Over 150 different plant species or species varieties were, thus, grown in one village in a year.

Schroeder also found that the farmers often tested crop varieties brought from other areas and different crop management techniques. In Nepal, a village can farm land over a vertical range of more than 1,500 m. According to Schroeder, farmers utilise very developed land and plant classification schemes to match cropping patterns and crop varieties with each of the small fields that they farm. In the process, the peasants have transformed the middle mountains leaving little of the original vegetation. Farmers in Nepal distinguish six different types of land use — *khet* (wet terrace), *bari* (dry terrace), *pakho* (untilled and infertile land), *charan* (grazing land), *ban* (forest) and *gaun* (settlement)[2]. Khets are highly valued terraces since they yield two key staples, rice and wheat. They require heavy labour for upkeep and irrigation control. Baris are rainfed terraces on higher elevations. They yield maize, legumes and other staples. Maintenance is easier but these terraces are prone to erosion and sliding due to weak soils. Pakho is untilled land, which is usually rocky or too infertile and steep to be cultivated. Charan is the commonly used grazing land, which often contributes landslides due to overuse and lack of upkeep.

Farmers have developed ways of dealing with the problem, especially through the deintensification of land use. When khet terraces are threatened with erosion or sliding, they are left uncultivated till they can be reused. Deintensification of khet to bari and bari to pakho in response to slumping terraces results in lower yields, but the farmers do it to save the land (see figure).

When farmers are alerted to signs that their terraces may fail by development of cracks (*dhanja*), slumping (*bhasinu*) or undercut wall sections, they may, in response, shift to a lower intensity of land use. In the case of a khet, they may decide to discontinue irrigation in order to reduce soil saturation and plant rainfed crops. In the case of bari, the field is left uncultivated until the terrace either collapses or is judged to be out of danger.

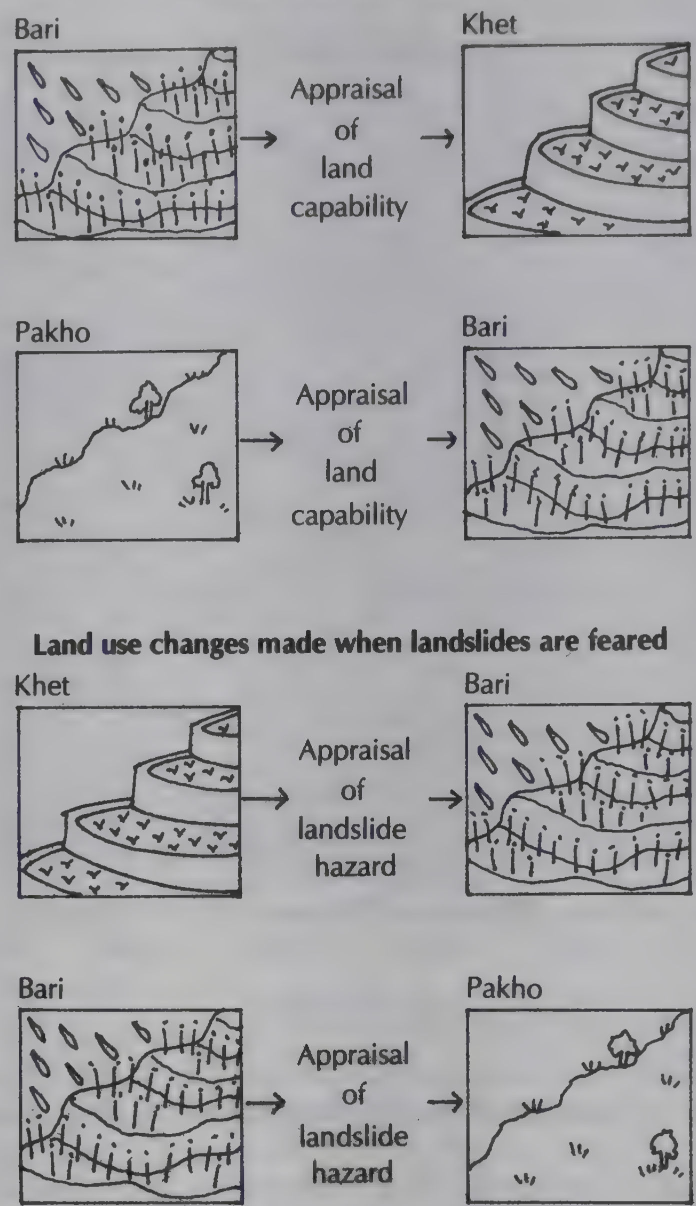
Pressing household needs result in an overall tendency to upgrade all agricultural land, that is, from pakho to bari and from bari to khet. Kirsten Johnson and his colleagues who studied environmental knowledge in Nepal say, "While some outside observers argue that this is precisely the process that leads to heightened hazard potential, from the farmers' perspective, the more valued the land, the more effort will be expended in its protection." The farmers realise that increasing population, tree felling and land use changes have increased the landslide problem compared to what it was a generation ago. But they argue that one of the main reasons for increased damage has been the construction of roads and buildings.

Though they would also like to put in more erosion control measures they cannot afford them. For instance, gabion structures (barriers of earth and stone encased in wire netting) appeal to them more than afforestation, but they are too poor to make such structures.

Government agencies must take heed of people's own knowledge and of the circumstances which force people to take certain actions they know may exacerbate the hazards. They must work with the people for effective measures against impending hazards.

Land use changes commonly made by farmers in Nepal

Desired land use change



Source : 2

Intensive land use can contribute to landslides. Himalayan farmers deal with this by deintensifying land use by shifting from Khet (wet terraces) to Bari (dry terraces) and from Bari to Pakho (rocky land) in response to slumping terraces, even though this leads to poorer yields. And wherever possible they try to upgrade the productivity of their lands.

Table 28

Roads in the Himalaya (1984)

Region/State	Area (sq km)	Total road length Actual (km)	Total road length Density (km/sq km)	Surface road length Actual (km)	Surface road length Density (km/sq km)
Jammu and Kashmir	222,236[1]	12,812	0.06	7,434	0.03
Himachal Pradesh	55,673	21,279	0.38	4,948	0.09
Uttar Pradesh hills[2]	51,125	NA	NA	12,423	0.24
Sikkim	7,096	1,291	0.18	1,229	0.17
Darjeeling hills[3]	3,075	NA	NA	69	0.03
Arunachal Pradesh	83,743	12,778	0.15	2,050	0.02
	422,948	48,160	0.13[4]	28.153	0.07

Notes : [1]Includes area under occupation of China and Pakistan
[2]Data relates to 1980-81
[3]Date relates to 1981-82
[4]Road density only of states for which data is available

Source : 89b, 89c for Uttar Pradesh hills and Darjeeling hills

of the same landslide scars. An inherently unstable landslide scar photographed in 1978 had become almost invisible by 1987 and the new terraces that had been made on the original scar were supporting vigorous crops of maize and rice in 1986.

It is not true that there are no problems of landslides, gullies and soil erosion in the Himalaya. But the available knowledge does show that, as human population numbers have increased, leading to conversion of forested land to agricultural terraces on steeper and more marginal slopes, more human energy is being spent to maintain a balance between stability and instability. The indigenous population has not been losing ground as rapidly as has been assumed. The local farmers definitely do not enjoy landslides which destroy houses, human lives, and livestock. The terror of sleepless nights in small houses on steep slopes during periods of torrential rain cannot be dismissed lightly. But at the same time some of the most densely populated and extensively terraced land in the lesser Himalaya probably experience some of the lowest rates of soil erosion and land loss. A very real danger of soil erosion and slope collapse would arise if such areas were abandoned. It is, therefore, not correct to blame local farmers for all these ills.

Studies by CSWCRTI confirm that conversion from forest to agricultural land use need not necessarily have a negative impact on either soil loss or water yield. Soil loss in an agricultural watershed treated with soil conservation measures dropped from 2.4 t/ha/yr to 0.2 t/ha/yr, volume of runoff dropped from 44 per cent of rainfall to two per cent of rainfall, and peak rate of runoff also dropped dramatically. As compared to a neighbouring forest watershed, the treated agricultural watershed had only 28 per cent of volume of runoff and the peak rate of runoff was only four per cent. Before treatment, both volume and peak rate of runoff were higher in the agricultural watershed[73]. Ecologically sound agriculture is, therefore, definitely possible in the Himalaya.

Impact of roads

Almost every human activity in the hills will directly or indirectly change existing slopes, slope forming materials and drainage system. As a result, all human activities can potentially increase soil erosion and landslides in fragile mountain areas. Several experts believe that road building activities have been the worst form of human interventions in the Himalayan mountains in terms of promoting soil erosion and landslides.

Prior to 1962, the Himalayan mountains were, for the most part, accessible only on foot. The few roads that existed led to hill stations like Mussoorie, Simla, Nainital and Darjeeling, located not very deep within the mountains. The 1962 Indo-Chinese war, however, prompted a massive road construction programme and roads now go into some of the remotest Himalayan areas. Over 44,000 km of roads now exist in the Indian Himalaya (see table 29).

Table 29

Soil loss due to road building in the Himalaya

Length of roads (km)	44,000
Debris removed to make these roads (mcum)	1,760 to 3,520
Debris generated by each kilometre of road per year (cum)	550
Debris generated by all Himalayan roads per year (mcum)	24.2

Source : 14

ROVING RIVERS

Changing courses by rivers is a constant problem in Bengal with the Padma and the Bhagirathi being the main culprits.

The Padma, which flows along the Indo-Bangladesh border on the northern boundary of Murshidabad district, has washed away many villages. Some 30,000 ha of arable land have been eroded, according to state irrigation minister Debabrata Bandyopadhyaya. The rate of erosion is sometimes over two metres a week during the monsoon. Journalist Debjani Sinha, who recently wrote on the plight of the people in the affected districts, describes the case of Ismail Sheikh who once lived on a sand bank along the Bhairav river, a tributary of the Ganga, also known as Mahananda. During the last decade, he has had to change houses six times due to the shifting course of the river. Bindu Ghosh, a resident of Nayansukh, once owned six ha of orchards, but owns only a few cattle and some utensils now. The Bhagirathi has washed away the land and his house four times. The rivers have created a new class of neorefugees constantly looking for a new home, some of whom have been forced to take to smuggling — an organised activity — along the Padma.

The state government has requested the Centre for money to protect the Padma's right bank — a vulnerable 94 km stretch downstream of the Farakka barrage. According to some, the main cause of river erosion is the Rs 160 crore Farakka barrage completed in 1975. Satyesh Chakravarti of the Indian Institute of Management is of the opinion that the barrage has accelerated erosion in the downstream reaches of the Padma. But to blame Farakka for all the havoc is unfair. As early as 1803, Major R H Colebrooke had found that the Padma was shifting westwards by 90 m a year. The Geological Survey of India has found that the distance between the Padma and Bhagirathi in Murshidabad district, which was six km in 1944, had come down to 3.3 km by 1966 and 2.9 km by 1975. The Pritam Singh Committee, set up in 1978 to examine the post farakka river ravages, also pointed out that the maximum distance between the Bhagirathi and the Padma is only a little over two kilometers with the minimum being only 30 m.

The committee warned that if the Padma breached its embankment, it could flow into the Bhagirathi, thereby, bypassing the Jangipur barrage and rendering it useless[1].

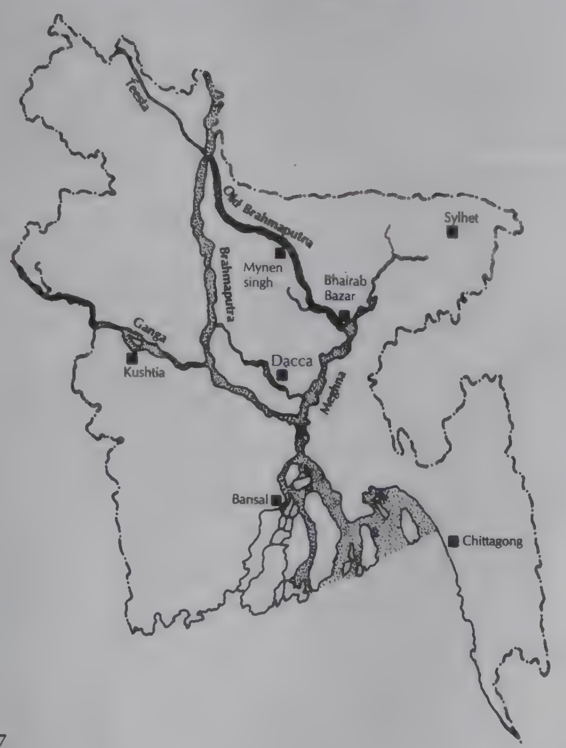
In Bangladesh also rivers constantly undergo migration. In the late 1760s, only 200 years ago, the Brahmaputra flowed a 100 km to the east of its current course. Long term patterns indicate that the Brahmaputra is moving westward[2].

A map of the area between the Ganga and the old Brahmaputra shows 28 distinct abandoned courses. Scientists disagree about the speed with which the Brahmaputra moved from the east side of the Madhupur jungle to its present course west of the area, which is probably the course mentioned in historic documents as the Jenai river. While one group believes that the change occurred in 1787 because of a heavy flood, another believes that the migration took place gradually between 1720 and 1830. At one time, the Teesta was not a tributary of the Brahmaputra but flowed into the Ganga, hugging the west side of the Madhupur jungle. Then the river migrated and joined the Atrai Gur to flow into the Meghna. But with the Brahmaputra moving to its present course, both the Teesta and the Atrai Gur have been captured by it and have become its tributaries.

It is not surprising that floods are common in the Bengal delta. Moderate floods occur at an interval of about four years, severe floods at seven years and catastrophic floods every 30 to 50 years.

FLOODED LAND: Bangladesh is the most flood affected country, India ranks a good second. (UNEP)

Rivers of Bangladesh



Source : 87

In Bangladesh rivers constantly undergo migration. Only 200 years ago the Brahmaputra flowed a 100 km to the east of its current course and the Teesta flowed into Ganga instead of Brahmputra.

Debris removal

Geologist K S Valdiya of Kumaon university claims that an average of 40,000-80,000 cum of debris is removed to build each km of these roads and another 550 cum have to be removed per km every year to maintain them.

This means that 1,760-3,520 mcum of debris had to be removed to make the Himalayan roads and another 24.2 mcum are removed every year (see table 29)[14].

Geographer Martin Haigh discovered 72 landslides larger than 10 cum in size, and total landslide debris of 1,105 cum per km on a six km stretch of the Mussoorie-Tehri road in 1978. A six km stretch of the Nainital-Kilbury road built in the 1980s, which runs through a reserved forest, revealed that 38 per cent of the road had slumped, 39 per cent of it was affected by rockfalls and there were 24 landslides per km of the road. Every year the landslide debris is pushed down the hill to keep the road clear, which damages the forest cover below and destabilises the hillside. The tree and vegetation cover below the road had been greatly reduced as compared to that above the road[81]. According to K G Tejwani, former director of CSWCRTI, 10 small to medium landslides occur on average over each km of Himalayan roads and most of them are the direct result of the slope instability caused by road construction[82].

FLOOD SUFFERING : Frequent floods cause enormous problems, with clean drinking water becoming a prized commodity. (Badal/Oxfam)

ROAD MENACE : The massive Kaliasor landslide in the Garhwal Himalaya — partly caused by the road and now a major problem in maintaining the road. (Amar Talwar/CSE)

R K Bhandari and Chanchal Gupta of the CBRI also believe that the stability of Himalayan slopes has been greatly jeopardised by roads. Road construction invariably involves deep cuts which set in a process of progressive failure. Because road construction agencies are keen to complete their roads rapidly, few efforts are made to protect the cut slopes or provide effective drainage. After the roads are built, they are ravaged by recurrent landslides and rockfalls during rains[27].

Increasing fears

Several geologists believe that landslides are probably increasing because of increased human activity, though no documented evidence is available. A meeting of landslide experts held in Gangtok in 1975 had expressed fears that landslides will increase because of growing development activities. More roads will be required and, as these roads open up new areas, forests and other natural resources will be heavily exploited. The combined result will be an increase in landslides and erosion[83].

Landslides and slope instability problems are now being noticed in numerous Himalayan towns. Natural drainage often gets blocked or obstructed by human activity and surrounding hillsides get denuded because of increased human pressure. In addition, dynamite is often used to blast the hills for construction which further destabilises the slopes[22].

While there is no doubt that increasing construction activity is probably increasing landslides and soil erosion and leading to serious local problems, it is not clear whether the increased erosion is sufficiently large to increase sedimentation on the scale of the Indo-Gangetic plains. The impact of this increased erosion is in all probability small over natural factors[33].

CONCLUSION

Himalayan environmental degradation is now widespread. The forest cover has declined rapidly and its place has often been taken by overgrazed lands. Modern human activities

like road building and commercial felling of trees have taken place in an ecologically destructive manner. It would, therefore, be wrong to say that Himalayan environmental degradation has no impact whatsoever on increasing soil erosion, surface runoff or landslides. Considering the fact that a wholesale conversion of forests to overgrazed shrublands has taken place, it can be argued that the local effects of ecological degradation on flood flows are sufficiently widespread to produce a general and regional effect.

But it would be equally right to say that these increases — over and above the levels dictated by natural factors — are probably far smaller than what environmentalists have implied — "perhaps in the tens rather than hundreds of percentages," as John Metz of the university of Wisconsin puts it[65]. Many more studies are needed to compare the impact of human factors with natural factors. But it is clear that the Himalayan range constitutes an extremely dynamic system that is naturally primed for disaster.

Runoff and silt tend to move out of the Himalaya in explosive waves. Landslides seem to be a major contributor of debri and soil to the rivers. Afforestation is unlikely to affect the scale and timing of these large geological processes. Floods are not new to the Indo-Gangetic plains. During the 3,500 years of recorded human settlement in the Ganga basin alone, there have been many floods of gigantic proportions.

Himalayan rivers have constantly changed their courses long before deforestation began. For example, archaeologists and scientists now believe that at the time of the Indus civilisation, Yamuna probably did not flow into the Ganga nor the Sutlej into the Indus. Instead they flowed into the Ghaggar — currently a small, seasonal river that emerges from the Siwalik foothills near Chandigarh — to make it a mighty, perennial river that flowed straight into the Arabian Sea without joining the Indus, probably the much worshipped Saraswati of the Vedic times.

Scientists believe that numerous floods and hydrological changes have taken place in the Ghaggar plains over the last three to four millennia, possibly associated with tectonic changes in the Himalayan foothills. Far more recently the Teesta used to flow into the Ganga until 1787[37].

The various district gazetteers of Bengal of the late 18th and early 19th century describe the havoc caused by the large movements of the rivers from place to place. Several major cities in Bengal have risen and fallen due to shifts in the river's location. For example, in 1540, Portuguese merchants described the very large, well fortified city of Gaur on the banks of the Ganga. By 1575, the river had deserted the city and it was abandoned. In the estuary, many large islands appeared almost overnight only to be washed away with tremendous loss of life several years later when they had been densely settled[61].

This process is still going on today in Bangladesh. Journalist Debjani Sinha recently reported that several rivers in West Bengal are changing their courses and causing immense riverside erosion leading to displacement of people living in the Murshidabad and Malda districts[84].

It is interesting to note that deforestation as a cause of floods has come to be cited only recently. The district gazetteers of Purnea and Saharsa written in the last century, though concerned about the high silt load of the river Kosi, have never alluded to deforestation as a contributory factor. Instead their recurrent emphasis was on the geological instability of the river's upper catchment.

To understand the problem of increasing floods in the Indo-Gangetic plains, it may be more instructive to study the ecological changes that have taken place in the flood plains themselves.

- *Over three-quarters of the plains area in Assam is flood prone. The valley is also the home of over 19 million inhabitants for whom floods are nothing new but their current ferocity is.*

- *The 1950 earthquake, one of the world's worst, has greatly affected the behaviour of the Brahmaputra. Prior to 1950, the river would rarely exceed the danger level at Dibrugarh. But since 1954, the river goes above the danger level more than once every year.*

- *The 1950 earthquake loosened enormous quantities of soil which was slowly washed down to the valley raising the river's bed.*

- *Since 1986, the ferocity of the floods seem to have increased considerably. The 1988 floods were devastating, they affected 4.22 mha out of the state's total area of 7.54 mha.*

- *By 1988, 4,000 km of embankments had been built in the state. But over 90 per cent of the protected area was affected by breaches in that year.*

- *Experts believe that embankments have created a situation for the worse by causing drainage congestion, and no more embankments should be constructed.*

- *As siltation takes place within the embanked area, the river bed rises rapidly. Dredging of the Brahmaputra has proved impractical.*

- *Natural factors contribute more to floods in Assam than deforestation or shifting cultivation. Northern tributaries of the Brahmaputra come from more forested areas than the southern ones yet create more floods.*

- *Reclamation of swamps in the flood plains has taken away an important natural cushion for floods.*

- *The government of Assam promotes megadreams. It wants large dams on the Barak, Brahmaputra and their tributaries. Agriculture and floods can be seen as two sides of the same coin. Restructuring of the cropping pattern is advocated by a former vice chancellor of the state's agricultural university to help people live more easily with floods.*

CHAPTER 4

Annual Mayhem in Assam

With floods affecting over three-quarters of the plains area of the state, they are not anything new for the 19 million inhabitants of Assam but their current ferocity seems to be unprecedented and fast becoming an annual ritual in Assam. The two rivers, Brahmaputra and Barak, together drain the land and year after year bring untold miseries for the people living in these two river valleys.

Lokeswar Makrari, the 70 year old chief of Modhupur Tinsukia village near Dibrugarh, remembers how he lived through wave after wave of floods in 1987. "It was a nightmarish experience," he recalls. "We still wonder how we managed to survive. With the water level rising fast, we had to move to safer places and also save our livestock. Most of us lost our houses, and the crops were wiped off"[90].

"Floods are not new to us, and we have learnt to live with them," adds Lokeswar Makrari. "But certainly not floods of this magnitude. The 1987 floods were much beyond our expectations. They struck in five waves, the fifth being the fiercest. It was the worst ever flood in my time. The irony is that in 1987 we had to plant four times, but with a succession of floods washing away the seedlings, we could not harvest a single grain." Officials in Guwahati echo his sentiments.

Large tracts are submerged every year. Water remains in the fields for a considerable time. Much damage is caused to the *kharif* crop[91]. Rice is the principal crop in the state. There are four basic varieties, namely, *Ahu, Bao, Sali* and *Boro.* Ahu is an early ripening variety grown on relatively higher grounds and harvested from June to August. Sali is the most important and is sown in seedbeds in June and July, transplanted in July or August and harvested from December and January. Boro is winter paddy grown along the margins of *bils* (swamps), transplanted in December or January and harvested from April and May. The Sali crops that occupy 75 per cent of the total cropped area are the worst affected by floods between July and September. If floods occur in early June, standing Ahu and Jute crops are affected. If they are late, August or early September, they leave no time for replanting of rice seedlings[92].

Survival after the floods is usually precarious. In 1987 the villagers of Modhupur Tinsukia sustained themselves with catches of small fish that came with the floods. Some eked out a living by cutting swamp grass and selling it as fodder. The situation was identical in most villages of the valley, only the scale varied. Moving villages around is not unusual for those who live along the banks of the Brahmaputra. Makrari's original village was on the bank of the river. But when the river changed its course, the old village became a part of the river bed.

So the village moved five km away from the old site. But, Makrari does not believe this is the end, "this place will also meet the same end," he says.

EXTENT OF FLOODS

The Brahmaputra basin, one of the most flood prone in India, extends over an area of 58 mha spread over Tibet, India, Bhutan and Bangladesh (see table 31). The river — 2,880 km long — originates in the great glacier mass of the Kailash range traversing nearly 1,100 km across Tibet before entering India through the eastern part of Arunachal Pradesh. In Tibet, it is known as Tsangpo and in Arunachal Pradesh as Dihang or Siang. After another 226 km of mountainous courses, the river enters the plains of Assam near Pasighat. At Kobo, 52 km south of Pasighat, Dihang meets two rivers called Dibang and Lohit, thereafter, its name becomes the Brahmaputra — the son of Brahma — the only male amongst a bevy of female rivers. After emerging from the hills, the river's gradient suddenly turns

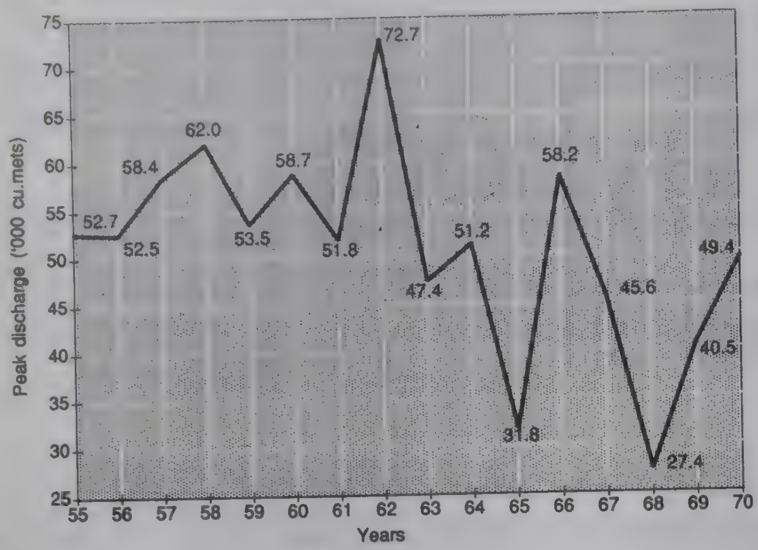
Table 31

Area of the Brahmaputra basin

Region	Area (mha)	Area (mha)
CHINA		29.3
BHUTAN		5.3
INDIA		18.7
Arunachal Pradesh	8.14	
Assam	7.06	
Meghalaya	1.17	
Nagaland	1.08	
West Bengal	1.26	
BANGLADESH		4.7
Total		58.0

Source : 5,121

Annual peak waterflow in the Brahmaputra (1955-1970)



Source : 163

The peak water flow in the Brahmaputra varies dramatically from year to year. Between 1955 and 1970, it ranged from a low of 28,000 cumecs to a high of 72,000 cumecs.

from a steep one to an almost flat incline — a gradient of 0.09-0.17 m/km near Dibrugarh (see figure 1). The river travels for 720 km through Assam finally leaving India at Dhubri to enter Bangladesh[79].

This journey is through an extremely narrow valley merely 80-90 km wide. While the eastern Himalayan ranges hem in the northern end of the valley, its southern end is first covered by the Patkai-Naga hills and Mikir hills of Assam, and then by the Khasi and Garo hills of the Meghalaya plateau[79]. The river is fed by tributaries both from the north and the south. Its major north bank tributaries are Subansiri and Jia Bharali, which flow in from Arunachal Pradesh, and Pagladiya and Manas, which flow in from Bhutan. Its major south bank tributaries are the Burhi Dihing from Arunachal Pradesh, Dhansiri from Nagaland, and Kopili from Assam's Karbi Anglong district. Most of these would be classified as major rivers in other parts of the world (see table 32 and 33).

During the monsoon months, the rainfall in the valley ranges from 2,480 mm to 6,350 mm[93]. Most of this water

Table 32

Water yield of major tribuatries of Brahmaputra

River	**Station**	**% of water yield of Brahmaputra (%)**
Dihang	Pasighat	34.00
Dibang	Jiagaon	7.65
Lohit	Digarughat	9.50
Subansiri	Chouldhowaghat	10.30
Other tributaries	Above Pandu	38.55
		100.00
Average annual yield of Brahmaputra at Pandu (mcum)		494.300

Source: 105

Table 33

Major tributaries of the Brahmaputra

	Entry into Assam from	**Catchment area mha**	**Average annual runoff (mcus)**	**Average annual sediment (mcus)**
Dihang (Siang)	Arunachal Pradesh	24.959	185,000	
Northern tributaries				
Burisuti	"		-	0.2
Subansiri	"	2.7	57,400	71
Ranganadi	"		3,300	14
Buroi	"		-	1.1
Borgong	"	0.04	1,500	1.2
Jia-bharali	"	1.42	25,900	171
Gabharu	"		-	1.0
Belsiri	"		-	0.8
Pachnoi	"		-	1.0
Dhansiri (north)	Bhutan		2,600	1.8
Noanadi	"		-	0.4
Nanoi	"		-	0.4
Barnadi	"		-	0.9
Puthimari	"	0.09	1,900	15.9
Mutanga	"		-	2.0
Darranga	"		-	0.2
Baralia	"		-	1.5
Nona	"		-	0.1
Pagladiya	"		1,200	2.0
Mora Pagladiya	"		-	0.7
Buradiya	"		-	0.3
Tihu	"		-	0.8
Kaldiya	"		-	0.7
Pahumara	"		1,400	1.2
Beki	"		-	175.4
Bhalukdoba	"		-	4.5
Manas	"	2.942	37,600	2.5
Buriaie	"		-	13.9
Southern tributaries				
Dibang	"		39,100	155
Lohit	"		46,600	147
Burhidihing	Arunachal Pradesh	0.492	13,600	181
Desang	"	0.365	4,200	8.4
Dikhow	Nagaland	0.36	4,200	3.1
Jhanji	"		1,700	1.3
Bhogdoi	"	0.06	-	1.3
Dhansiri (south)	"	1.024	-	13.3
Kopili	Assam	1.454	9,400	10.4
Digaru	Meghalaya		-	0.7
Kulsi	"		2,300	0.05
Deosila	"		-	0.1
Dudhnoi	"		-	0.2
Krishnai	"	-	0.7	
Jinari	"	-	0.2	

Source : 79 (for names of tributaries and data on sediment load), 121a (for data on average annual runoff), 122 (for catchment areas)

comes pouring down from May to October. The river then has no end. It is like a sea with no shore in sight. In the non-monsoon months alone, the river channel occupies an average width of eight km, that is, about one-tenth of the width of the valley[79]. But when in spate, the river spreads itself 10-16 km in width[94]. Yet with over 40 per cent of the valley's area under cultivation, the Brahmaputra valley in Assam is the home of more than 19 million people.

Not surprisingly, floods are inherent to the ecological situation of Assam. Not much is known about the floods that took place before the advent of the British, but there are records galore of floods during the British period in district gazetteers. The 19th century saw massive floods in Goalpara, Kamrup, Darrang, Nowgong (now Nagaon), Sibsagar and Lakhimpur districts[93]. Floods have occurred regularly in this century. According to data collected by the Central Water Commission (CWC) from 1953 to 1984, an average of 0.8 million hectares were affected by floods each year. The maximum area affected was 3.15 mha in 1954. The maximum population affected was 5.68 million in 1984. The maximum damage in a year — Rs 56.18 crore — occurred in 1983 whereas the average annual damage has been around Rs 13.9 crore (see table 34)[6].

The people in Assam strongly feel that floods are increasing. The available data shows clearly that the average area affected by floods during the 1980s was higher than in any of the previous decades for which data is available. The 1988 flood affected 4.22 mha — well over the earlier maximum of 3.15 mha in 1954. The largest number of people ever affected was also in 1988 — 12.68 million.

The number of people affected per hectare of flood affected area and the amount of damages per hectare of flood affected area have been rising steadily (see table 35). While this can be partly explained by the increasing human occupation of the flood plains and monetary inflation, experts believe that they are now witnessing a new phenomenon in terms of the number of flood waves they face every year.

Since 1986, floods have turned from bad to worse. The 1986 floods were said to be the worst in memory. When the floods came in 1987, they were called 'unprecedented'. But the floods in 1988 turned out to be even more devastating. In 1987, 16 out of 18 districts (with the exception of the hill districts of Karbi Anglong and north Cachar) were affected and in 1988, 17 out of 18 districts (with the exception of north Cachar only) were affected.

Table 34

Annual floods in Assam

Year	Area affected (mha)	Crop area affected (mha)	Population affected (m)	Total damages (in current prices) (Rs crore)
1953	0.08	NA	0.41	2.66
1954	3.15	0.27	1.68	15.77
1955	1.41	0.09	0.80	3.71
1956	0.60	0.08	0.56	3.26
1957	0.40	0.02	0.31	4.52
1958	1.25	0.07	0.47	2.70
1959	1.04	0.19	1.76	8.40
1960	0.47	0.22	1.32	7.76
1961	0.19	0.02	0.25	0.58
1962	1.62	0.38	4.05	20.32
1963	0.58	0.08	0.83	2.06
1964	0.76	0.15	0.77	2.46
1965	0.60	0.02	0.24	0.69
1966	1.78	0.40	4.65	22.53
1967	0.26	0.07	0.68	2.44
1968	0.41	0.13	0.92	8.36
1969	0.81	0.10	1.47	8.47
1970	0.72	0.20	1.71	10.43
1971	0.36	0.11	0.67	5.63
1972	1.10	0.38	3.20	24.15
1973	2.75	0.29	2.29	16.49
1974	1.12	0.26	2.85	19.24
1975	0.01	0.01	0.03	0.34
1976	0.57	0.11	1.46	11.98
1977	1.10	0.45	4.55	31.08
1978	0.31	0.08	0.92	4.27
1979	0.67	0.24	2.35	28.16
1980	1.16	0.29	3.36	39.80
1981	0.46	0.07	1.36	7.40
1982	0.61	0.10	1.42	21.90
1983	0.73	0.14	2.26	56.18
1984	1.52	0.49	5.68	50.82
1985	0.65	0.08	2.37	NA
1986	0.43	0.32	2.35	204.59
1987	3.08	0.99	9.46	50.61
1988	4.22	1.13	12.68	708.84

Source : 6 (for data from 1953 to 1984), 92 (for data for 1985 and 1986) and 105 (for data for 1987 and 1988).

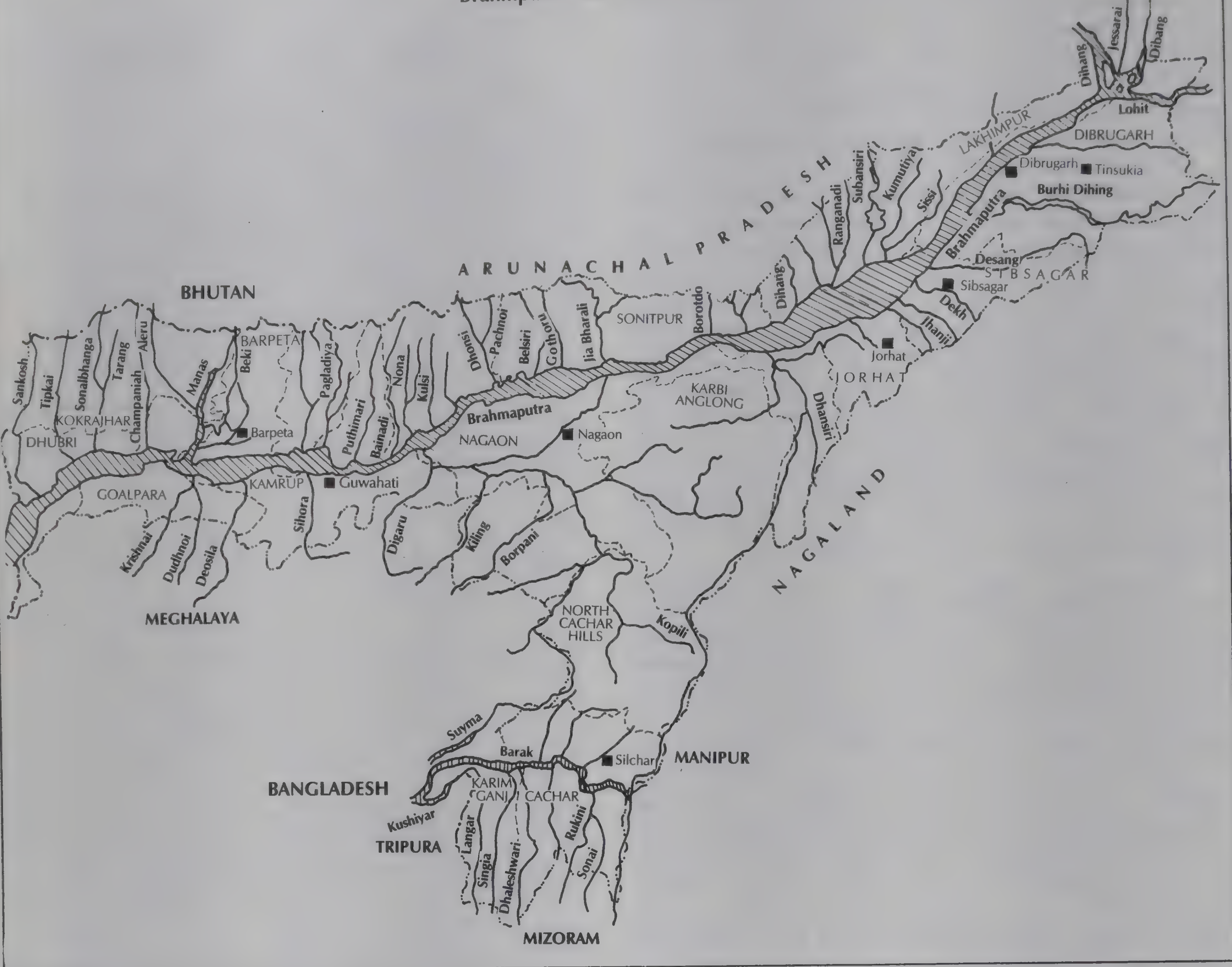
Table 35

Flood damage trends in Assam

Period	Average area affected per annum (mha)	Average annual crop area affected: Actual (mha)	Average annual crop area affected: % of total area affected (%)	Average population affected per annum (m)	Population affected per hectare of area affected by floods	Average total flood damages per year (Rs. crore)	Average annual crop damages as % of total flood damages (%)
1953-59	1.13	0.10	8.85	0.86	0.76	5.86	66.02
1960-69	0.75	0.16	21.33	1.52	2.03	7.57	92.33
1970-79	0.87	0.18	20.69	2.00	2.3	15.18	89.33
1980-88	1.43	0.40	28.05	4.55	3.2	142.52	96.38

Source : 6 (for data from 1953 to 1984) and 92 (for data obtained from 1985 to 1988)

Brahmputra and Barak valleys



The 1986 floods were called unprecedented because they occurred in October, when floods do not occur. Cyclonic depressions in the Bay of Bengal brought down heavy rain in the Northeast in the first and second week. Several areas were inundated suddenly, especially Nagaon and Jorhat districts. The expert committee set up by the government to look into the 1986 floods observed, "Of late flash floods are occurring in several medium to small rivers in Sibsagar and Jorhat districts with streams like the Bhogdoi, Mitong, Teok, and Disoi. In years to come a dangerous situation may prevail. A flood in the Brahmaputra together with flash floods in some of the tributaries will result in a desperate situation."

In 1987, floods came in several waves. In 1988, they came in five waves. In May, the first wave swamped 16 districts affecting 1.5 million people. The second in June affected 2.4 million people spread over 17 districts. A third wave affected four districts in July. The fourth in August — the most severe — swamped 17 districts. A total of 3.82 mha and 8.41 million people were affected by the fourth wave alone[92]. Some districts like Nagaon and parts of Karbi Anglong even experienced a fifth wave[95]. The damage to crops alone was estimated by the state government at Rs 334 crore[92].

In normal years, about 2,000 villages are affected. But in 1987, the number was 7,290 and in 1988, it was 8,770 (see table 36)[93]. The number of villages in Assam is 21,995 (as per 1971 census). Hence nearly 40 per cent were floodhit in 1988.

Table 36

Villages affected by floods in Assam

Year	Number of Villages
1982	3600
1983	4403
1984	4699
1985	3006
1986	2181
1987	7290
1988	8770

Source : 92 (data for 1988) and 121 (data from 1982 to 1987)

As the geographical area of Assam is 7.54 mha, the flood prone area averaged about 40 per cent until 1988. But with the largest flood affected area going up in 1988, the flood prone area also went up to 62 per cent. However, if the two hill districts of Karbi Anglong and north Cachar are excluded to get an approximation of the plains area of Assam, 77 per cent, or over three-fourths, becomes flood prone and went under water in 1988. The available figures show that one million hectares (or about one-sixth of the plains area of Assam) can go under water as many as four times in a decade.

Politics of relief

Assamese society is today caught in a vicious cycle, where floods consume an enormous amount of available human and financial resources for rehabilitation and loss of crop production and livestock results in massive unemployment and destitution. Flood relief and flood control have assumed a political dimension. Politicians, both at the state and the Centre, rarely discuss long term measures. The focus is always on short term measures like flood relief. Nearly every year the Prime Minister visits affected areas and adhoc sums for relief are announced. Quick assessments are made by the state government of damages caused to public and private property. The Centre rarely agrees with its assessment. The state is invariably starved of funds. The Central government invariably alleges that the grant is channelised for other purposes.

In 1987, relations with the Centre plummeted. The Centre was accused of not providing adequate flood relief funds because Assam was not ruled by the Congress-I. Ataur Rahman, a MP of the ruling Asom Gana Parishad, sent a telegram to the Prime Minister in August 1987 : "Great resentment is building up due to apathy of Central ministers and bureaucrats . . . no financial assistance given despite third wave of unprecedented floods covering more areas than last year. Central ministers and MPs have no time to come to Assam"[96]. Murali Manohar Joshi, general secretary of the Bharatiya Janata Party complained: "The government of Rajiv Gandhi did not even think it necessary to provide interim relief. Neither the President nor the Prime Minister in their Independence Day speech ever mentioned the flood havoc in Assam" [97]. The state government requested the Centre to release Rs 30 crore as interim relief. It estimated the total loss at Rs 400 crore. The chief minister regretted that the nation did not come forward to help the people in their hour of agony[98].

Within the state, political parties accused the ruling AGP of discrimination while distributing relief. The United Minority Front (UMF) complained that in several districts, relief was inadequate and people of those districts were being discriminated against. Congress-I workers complained that the workers of the state's ruling party were controlling all relief operations. Other political parties could not participate in the flood relief activity. The Assam State Flood Relief Committee founded in 1974 to supervise relief measures, with the chief minister as the president and an opposition MLA as the general secretary, had become defunct[99].

In 1988, after the fourth wave of floods, the Prime Minister went to Assam. The chief minister, Prafulla Kumar Mahanta, refused to receive him at the Dibrugarh airport. The Prime Minister accused the state government of misusing relief funds and of diverting them to less priority areas[100]. The state's ruling party stated that the Prime Minister was playing dirty and misleading the nation[101]. Regarding the delay in the release of funds, the Prime Minister said that the state government had not submitted its official memorandum on time[100]. Mahanta replied that Central government forms require vast amounts of data which can be collected only after the floods recede[101].

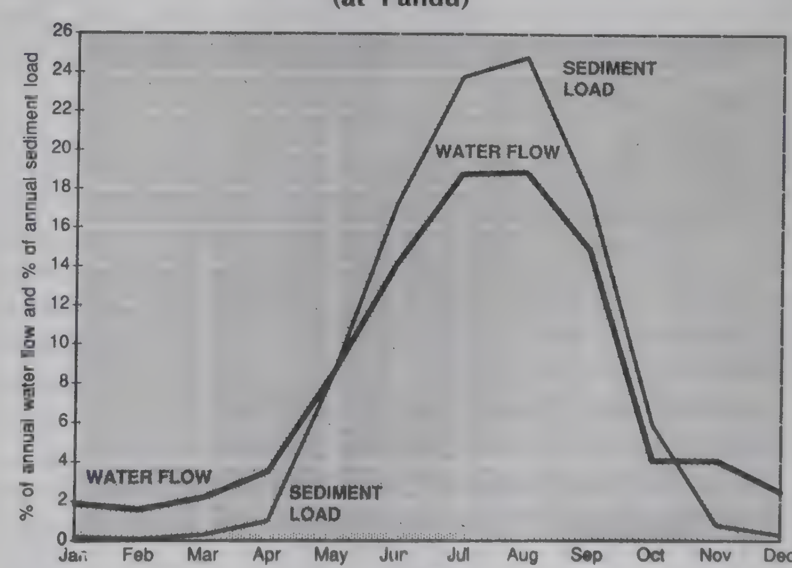
UMF's Abdul Hameed complained bitterly of the rampant corruption in the flood control department of the state government and of a nexus between contractors and officials. The MP also claimed that many people displaced by the erosion of the river banks, who had started coming into towns in search of jobs, were being harassed by officials as illegal Bangladeshi immigrants[102].

In short, when floods come to Assam, politicians fight more amongst themselves and think more of how they can get more money — much of which allegedly goes to line their own pockets and those of contractors and officials — than of helping the people. This annual ritual gets played out every year while the distressed of Assam wait and watch.

CAUSES OF FLOODS

In Assam, floods are the combined result of natural, ecological and anthropogenic factors. The Brahmaputra and its tributaries emerge from mountains, which are not only highly erodible but also seismic. The Brahmaputra is one of the leading sediment transporting rivers of the world[79]. During the monsoon, the river carries an average of 2.12 mt of sediment per day[103]. Several experts have blamed deforestation and shifting cultivation in the adjoining hills for this heavy silt load. Although this is partly true, other

Monthly water flow and sediment load of Brahmaputra (at Pandu)



Source : 121a

Sediment load in the Brahmaputra is very low at low water flows but rises sharply with increasing water flows.

NORMAL DISASTERS

In a sickening pendulum like fashion, the water levels of the rivers in the Brahmaputra valley rose three times in 1989, ravaging Assam with serious floods even as most of the surrounding states were shaken by devastating landslides. Unprecedented floods rampaged through the Barak and Imphal valleys and the Indian Air Force (IAF) had to organise its biggest ever peacetime airlift. Nevertheless, if statistics are to be believed, it was a normal year for the Northeast, which soon faded out to become part of newspaper clippings in musty files.

The following is a synopsis of the events that made up the horror of 1989. On June 6 the Brahmaputra shouldered its way into the low lying areas of Guwahati. The row the state press would later make over the Assam floods began as a whisper.

The first wave (June 16-17 – June 25)

The first wave began on June 16. Heavy rains for several days preceded the rising of the Brahmaputra above the danger mark at Dibrugarh in upper Assam, a trend universal along its 800 km course till Dhubri in lower Assam. Its tributaries — Burhi Dihing, Jia Bharali and Gabharu, which come from Arunachal Pradesh, and Kopili from Cachar hills — followed suit. Meanwhile its northern tributary from Bhutan, Puthimari, breached its embankment in Kamrup district.

The devastation which began on June 18 lasted till June 25. Flowing through a 60 m breach Puthimari displaced 24,000 people in 17 villages. Jia Bharali ravaged Sonitpur district, Belsiri from Arunachal rose up in Darrang district and Beki and Manas coming from Bhutan adopted threatening postures in Barpeta district. Amongst this havoc, reports began to trickle in of landslide disasters upstream in Arunachal Pradesh.

By June 19 about 200,000 people in Sonitpur, Darrang, Barpeta and Kamrup districts were affected by the swollen northern tributaries and Gonagadhar had flooded Dhubri district. The next day even as floods began to recede, the Puthimari extended its sway over fresh areas in Kamrup district. At this time, troops were being rushed to Arunachal Pradesh to combat the landslide disasters in the area.

In Arunachal Pradesh, landslides on June 13 cut off East Kameng, West Kameng and Tawang districts. A 42 km stretch of road between Dirang and Bomdila suffered 113 landslides. Officials even claimed that 25,000 troops were marooned in the state. The landslides led to the formation of temporary dams upstream and sparked off flood pulses when these dams broke, creating mayhem downstream. The latter, however, was reported before the former because of its proximity to the public eye.

The second wave (June 2 – July 22)

On June 25, the first wave of floods receded like a bad dream, but even before a paralysed Assam could awaken from its stupor, the nightmare began again five days later. The Brahmaputra began to rise again, Guwahati became waterlogged for the second time in the season and the northern tributaries of the Brahmaputra went berserk. On July 2, Manas, Pagladiya and Dhansiri went wild with a lust for land. Within 24 hours even the oilfields were flooded and authorities struggled to save the embankment at Bhojmari from the rebellious Brahmaputra.

Amid this frenzy Assam's finance minister was forced to admit that the food situation was critical and the IAF launched relief operations for 0.15 m people stranded for nearly 20 days.

In the meantime, a war of words broke out in the press provoked by the waterlogging of Guwahati with *The Sentinel* in the forefront of the attack condemning the lack of foresight and planning in the city's growth. The paper claimed that low lying paddy fields had been acquired for housing projects. To make matters worse, the railtracks acted as an obstruction to the flow of rainwater as they had been laid down ignoring the natural drainage of the land.

Even after the summer vacations were over educational institutions were unable to open in Arunachal Pradesh as 1,000 teachers could not make their way back to the schools. The Communist Party of India and the Peoples Party of Arunachal tried to make political capital out of the situation. Meanwhile, nature took its own course, the Jorhat district was flood hit with 60 villages as the main victims. The next day on July 5, Dihing breached its embankment and 37,000 people became flood victims in Sibsagar district overnight. To add to their woes, airdropping operations in Arunachal Pradesh came to a grinding halt with the setting in of inclement weather. In the three districts of Arunachal Pradesh, cut off for over 20 days, the death toll was now estimated to have mounted to 26.

As army and police boats were pressed into service to rescue 50,000 people marooned by the Dihing, the Brahmaputra and its tributaries, like gigantic pythons encircled 500 villages in Sibsagar, Dibrugarh, Jorhat, Golaghat, Lakhimpur and Dhubri districts, washing away eight villages in Nagaon district. While Assam chief minister P K Mahanta was appealing to the Centre for help, the Brahmaputra's northern tributary, Subansiri, washed away 0.5 km of an embankment in Lakhimpur district.

In Arunachal Pradesh, chief minister Gegong Apang termed the mid-June devastation as unprecedented and called for Central assistance to the tune of Rs 25 crore. In Assam, focus moved from one crisis to another till finally the turbulence ceased and the rivers calmed by July 22. By July 25, road transport began to ply between Bomdila and Tawang, but the Bomdila-Tezpur road was still to be restored.

The third wave (July 30 – August 12)

July 22 to 29 was only the lull before the storm. Assam was yet to suffer a third wave of floods. The subdued waters of the Brahmaputra and its northern tributaries from Arunachal Pradesh and Bhutan — Subansiri, Puthimari, Pagladiya, Manas, Jia Bharali and Gabharu — became feverish with activity and overflowed the danger mark. To make matters worse Guwahati, was waterlogged for the third time. Needless to say this was preceded by incessant rains.

On July 30, flood waters in Manipur toppled the embankment and rushed into the town of Imphal. Road communications between Guwahati and upper Assam were severed as the road near the Kaziranga National Park went under water. Bhogdoi coming down from Nagaland breached its embankment downstream from Jorhat and heavy landslides around Guwahati hillocks claimed several lives. Heavy landslides succeeded in cutting off the Tezpur-Bomdila road in Arunachal Pradesh again, which had been restored after five weeks. In Meghalaya the Shillong-Silchar highway was closed down and the Shillong-Guwahati road cut off. In Mizoram, landslides blocked the Aizawl-Silchar road claiming several lives and Saiha town was marooned by landslides and floods in the river Kolodyne.

In the Barak valley all major rivers, Barak, Kushiara and Kutakhal, went into spate and Sonai and Longai coming down from Mizoram breached their embankments. By August 1 surging waters had displaced 10,000 people in Silchar. Meanwhile in the Brahmaputra valley, Dhansiri and other rivers inundated 64 villages affecting 0.1 m people in Golaghat district. In Sibsagar

district, the southern tributaries, Dikhow, Jhanji and Desang breached their embankments. At the same time, the army was busy carrying out rescue operations and plugging breaches along the embankments of Imphal and Iril rivers in Manipur. To make matters worse, heavy landslides cut off the road link between Nagaland and Manipur. Central minister Rajesh Pilot who surveyed the area described the damage as unprecedented.

Suddenly large parts of Silchar were submerged as the Barak, resembling a large sea, swamped the area displacing one million people in the Barak valley.

For the next few days, chaos ruled the Northeast. Floods in Manipur were described as the worst since 1966. Landslides in Mizoram destroyed more than 500 houses. In Assam, officials claimed that over 2.5 m people were flood affected. By August 5, the rising Loktak lake had engulfed 41 villages in Manipur and continuous rains had aggravated the situation in the Barak valley where 74 breaches occurred in embankments, 63 of them in Cachar district alone. By now Guwahati-Silchar highway was under five to six feet of water.

Meanwhile, the Ghaghara broke through its embankments to flood parts of Silchar. There was speculation that the tea industry might be paralysed. The following day Assam officials claim that 2.37 m people were affected in 3,135 villages spread across 13 districts. Most of this havoc, in upper Assam, was caused by the northern tributaries of the Brahmaputra and not by the river itself.

On August 12, the Eastern Air Command of the IAF claimed that it had to launch its biggest ever peacetime airlift to reach out to flood and landslide victims in Arunachal Pradesh, Manipur, Mizoram, Meghalaya and Assam. Helicopters and planes were the only way to reach the stranded people not only in remote mountains but also in cities like Silchar which were under a vast sea of water.

Journalists taken on an inspection tour reported that 57 major and 112 minor landslides in Arunachal Pradesh in mid-June had badly damaged the only road connecting Tawang, East Kameng and West Kameng districts. A stretch of 1.3 km had simply caved in. Chief Minister Apang expressed the opinion that only seismic activity could have caused such widespread damage. Journalists also received contradictory statements on deforestation. While state officials claimed that there was "absolutely no deforestation in the area," one official, who preferred to remain anonymous said that 5,000 to 7,000 truckloads of timber were smuggled out of the region everyday.

Manipur chief minister, R K Jaichandra Singh claimed that the 1989 floods were the worst in the century, especially as they came so suddenly that everybody was caught unawares. Assam officials claimed that 1989 saw the second worst flood in the Barak valley in 100 years. The 1929 floods were very bad when the Barak rose to an all time high of 22.89 m as compared to 22.03 m in 1989. But damages in 1989 surpassed all previous records. A senior engineer of the Border Roads Organisation claimed that tremors in April and mid-June were responsible for the landslides in mid-June in Arunachal Pradesh together with the 1,200 mm of rainfall that came in three days from June 13 to 15. Finally, on September 13, a Central team arrived in Assam to assess the damage. The usual began to happen.

The last editorials were written in mid-September. Soon the papers dropped the subject of floods altogether and the disaster of 1989 breathed its last in a dingy corner of the nation's conscience.

experts believe that geological processes, which cannot be stopped, constitute the major factor. The expert committee on 1986 Assam floods concludes: "River behaviour, to a large extent, is governed by the geology of the basin and seismic stability. All the valleys in Assam consist of friable rock and silty earth. The area is earthquake prone and the rivers have a tendency to meander and create flood problems by creating drainage bottlenecks. This phenomenon is omnipresent at flood time in the watersheds of all the tributaries of the Brahmaputra and the Barak"[93].

The tributaries on Brahmaputra's north bank create more floods than those on its south bank. The northern tributaries have steep slopes, shallow and braided channels, and coarse sandy beds. They carry a heavy silt charge and have a tendency to bring flash floods because of the short distance between their source in the hills and their confluence with the Brahmaputra. The south bank tributaries have comparatively flatter gradients, deeper channels right from the foothills, are clayey and, hence, more stable beds and banks. They also carry a comparatively low silt charge though they come from heavily deforested areas. Floods caused by south bank tributaries are less widespread[5].

The Brahmaputra valley and its adjoining highlands are extremely seismic. Major earthquakes are expected to occur once every 30 years[79]. The latest, in August 1988, had a magnitude of 7.3 on the Richter scale[104]. Between 1920 and 1969, 416 shocks of magnitude five and above occurred in the Northeast[5]. Over 2,500 earthquakes occurred between 1970 and 1988 within a radius of 450 km from the Central Seismological Observatory at Shillong[104].

Earthquakes have often resulted in enormous quantities of silt and debris being washed down into the plains and in the rising of river beds. The earthquakes of 1897 and 1950, both of which recorded 8.7 on the Richter scale, are among the most severe in world history.

Both caused extensive landslips and rockfalls in the hills, subsidence and fissuring of the ground in the valley, and greatly disturbed the topography and the drainage system of the Brahmaputra and its tributaries[79]. While the former did much damage to lower Assam, the latter affected upper Assam, whose epicentre was near Rima in Arunachal Pradesh[104]. As a result of the 1950 earthquake, extensive landslides occurred on the Himalayan slopes, temporarily blocking the courses of the Subansiri, Dibang and Dihang.

Bursting of these landslide dams after several days released an enormous amount of impounded water, producing devastating floods downstream. The sediment generated by the landslides was brought down into the rivers, raising their beds considerably. At several places, channels of the Brahmaputra were choked with sediments released from fissuring of the ground[79]. Even the low water levels of the Brahmaputra at Dibrugarh rose by three m after the 1950 earthquake and the bed of the Dibang silted up by six m near Sadiya[5]. After the earthquake of 1950, the erosive activity of the river along its banks also increased. Sadiya town at the confluence of Dibang and Lohit disappeared in 1953. A major portion of the Palasbari town was destroyed in 1954 and so was the best part of Dibrugarh[5]. The old court building, which was

TERRIFYING TREMORS

In his book *Waters of Hope,* journalist B G Verghese describes the four "great earthquakes" that have occurred in the Indo-Nepal Himalayan belt over the past one hundred years[1]. Possibly the very greatest ever recorded anywhere in the world was the 1897 earthquake in the Shillong plateau measuring 8.7 in magnitude and felt over a vast area of 448 mha — an area larger than the size of India. There was a 10 m vertical displacement over a length of 20 km along the Chedrang fault and groundwaves were clearly visible. Aftershocks continued for 10 years. The Kangra earthquake of 1905 recorded 8.5 and was felt over 416 mha and apparently uplifted Dehra Dun by 12.7 cm. The north Bihar-Nepal earthquake of 1934 was felt over 91.6 mha and measured 8.4. The most recent of the great Himalayan earthquakes occurred on August 15, 1950. It had its epicentre a little northeast of the Indo-Burma-Tibet trijunction and measured 8.6 placing it among the five greatest earthquakes known in historic times. The shock was felt over 290 mha. It savaged the eastern Himalaya and altered the drainage of the upper Brahmaputra system.

The main shock was variously said to have lasted about four to five minutes with an energy several million times that released in the explosion of an atom bomb. From aerial reconnaissance it appeared that about 1.56 mha were affected by severe landslides. Taking an average depth of about three metres a geologist estimated the total volume of earth removed to be of the order of 46,000 mcum.

Extensive landslides blocked the Subansiri and other rivers, the dams bursting a few days later caused immense flood havoc. A huge block of rock "about four miles in length and a quarter mile in width" dammed the head waters of the Tidding 120 km up the river from Sadiya which was itself obliterated as the Dibang changed its course. The Lohit was also dammed. The government even thought of bombing the dam to avoid a dam burst but soon gave it up as unfeasible.

The speed of the current flowing down the angry Brahmaputra at Pasighat was estimated from 45 to 75 km per hour for some time after the earthquake and waves of four to six metres were noticed. The rivers were choked with silt and the bed of Brahmaputra rose on an average by 1.5 m in the vicinity of Dibrugarh. Rivers changed course and navigation was disrupted over a distance of 64 km below Dibrugarh. The Ranganadi, Dihang, Dibang and Lohit valleys were most affected, landslides and erosion extending up to 5,000 m altitude on the MacMohan line along a 300 km arc.

The well known plant explorer, F Kingdom-Ward, and his wife were camping beside the Lohit near Rima in Tibet when the earthquake occurred, starting with "an appalling noise." The "first feeling of bewilderment — an incredulous astonishment that these solid looking hills were in the grip of a force which shook them as a terrier shakes a rat — soon gave place to stark terror. The din was terrible; but it was difficult to separate the noise made by the earthquake itself from the roar of the rock avalanches pouring down on all sides into the basin. Within two hours, the air was so thick with dust that every star was hidden; we breathed dust, it gritted our teeth, filled our eyes.. The destruction extended to the very tops of the main ranges, 15,000-16,000 feet above sea level. No wonder the mountain torrents began to glow (sic) intermittently as the gorges became blocked, followed later by the breaking of the dam; whereupon a wall of water, 20 feet high would roar down the gully, carrying everything before it and leaving a trail of evil smelling gray mud. Everywhere the scraped cliffs glistened white in the sunshine."

Damage to plant and animal life, fish and birds was enormous. The very topography of upper Assam was recast and the morphology of the Brahmaputra underwent dramatic change. E P Gee, the distinguished naturalist noted, "The silted up river beds in the plains areas could not contain the flood water, and consequently vast tracts of adjacent land became inundated, some for the first time in recorded history. The gradual westward movement of the colossal silt deposits down the Brahmaputra valley may be completed within a decade or two. And until new and deeper channels can be formed by the rivers of these alluvial plains the widespread flooding experienced in 1951 will be an annual occurrence, and may even worsen."

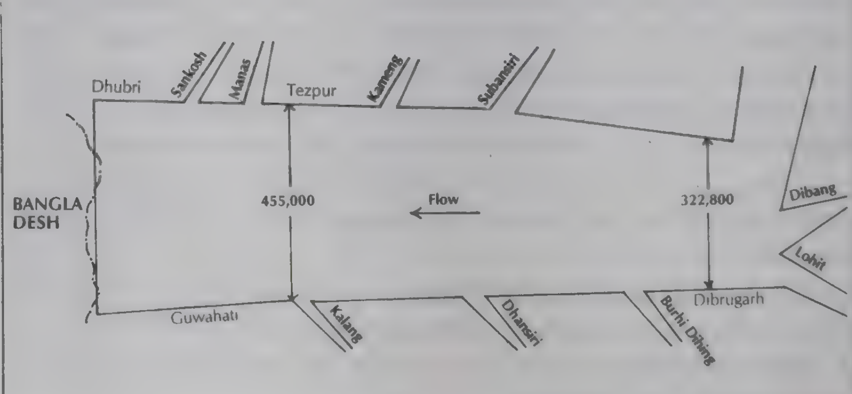
Gee's prediction turned out to be very correct. Studies carried out in the 1980s by Guwahati university geographer, D C Goswami found that the siltation rate in Brahmaputra river had increased considerably in the years after the earthquake. Loosened earth caused by the earthquake entered the river during the monsoon for several years. The sediment load in the Brahmaputra during the period 1956-71 was considerably higher than the period of 1971-77 [2]. Similar results have been found even further down in Bangladesh. Measurements at Bahadurabad have shown that the "dominant low water level in the Brahmaputra of 11.9 m in the early 1950s had gradually gone up to 13.4 m, a rise of 1.5 m, in the 1960s. However, since then a lowering trend can be observed"[1].

in the centre of the town, now stands on the bank of the river[90].

River dynamics

D C Goswami of Guwahati university has presented a detailed account of erosion and sedimentation in the Brahmaputra basin[79]. The region's tectonics, geology and climate of the basin have combined to generate high erosion rates and river channel changes, making the valley extremely flood prone. The hydrologic regime of the river responds to the seasonal rhythm of the monsoons with its Himalayan areas receiving an average of 5,000 mm of rainfall per year. The six months from May to October account for 82 per cent of the average annual flow of the Brahmaputra at Pandu. Compared to other major rivers of

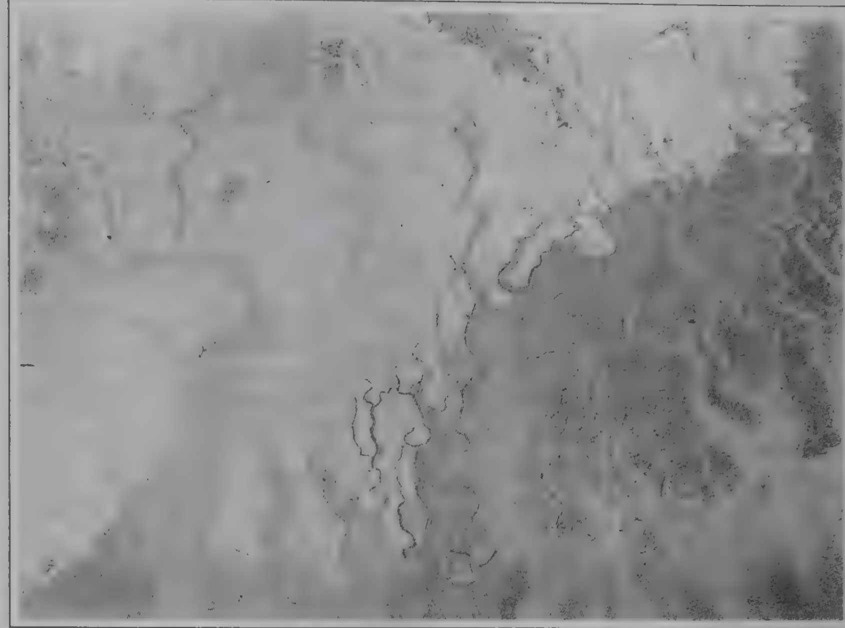
Average annual flow in the Brahmaputra



Note : The figure shows average annual flow in million cubic metres.

the world, the rivers of the Brahmaputra basin bring down some of the highest discharges of water per unit area of the basin. The Jia Bharali, a major north bank tributary, for instance, carries an average annual discharge of 0.0858 cumec/sq km and the Brahmaputra 0.0306 cumec/sq km at Pandu.

The Brahmaputra and its tributaries also bring down enormous quantities of sediments. The Brahmaputra flows in a highly braided channel characterised by numerous sand bars and islands, including Majuli, the world's largest river island. Most of the channel bars in the Brahmaputra are transient in nature. They get submerged during high flows and change drastically their shape and location. The channel of the Brahmaputra, thus, undergoes large changes every year. As river flows increase, the sand bars begin to move. When flows recede, sediments get deposited again as sand bars and islands and the river takes on a new profile. Between 1955 and 1979, the river transported an average of 402 million tonnes of sediments every year at Pandu. More than 95 per cent of this annual load was transported between May and October. Goswami's studies show sediment load increases rapidly with increases in water discharge. Floods are, therefore, responsible for the transport of the bulk of the sediments. Sediment load in the Manas river, which comes down from Bhutan at a steep gradient of 19 m per km, increases so fast with changes in water discharge that probably no other river in the world matches it in this characteristic. As many as 17 of Brahmaputra's tributaries yield sediments over five tonnes per hectare of catchment per year, the highest being the Jia Bharali (see



HEAVY STUFF : A satellite picture of the Bengal delta showing enormous fingers of silt moving down into the Bay of Bengal, evidence of the extraordinary silt load of the Ganga and the Brahmaputra. (NRSA)

SHRINKING ISLE

Majuli, the largest river island in the world has a population of nearly 150,000 and an area of 0.15 mha. Unfortunately this has been reduced by a third in less than two decades. The island's population is equivalent to that of a class I town. It houses two higher secondary schools, 37 high schools and a 30-bed hospital. However, it is facing severe erosion by the Brahmaputra and Subansiri. The channel of Kherkutia Suti, a third stream which used to join the confluence of Brahmaputra and Subansiri, has been closed off by a check dam.

The Sumoi Mari channel cuts across the island. Only 10 metres wide a couple of years ago it has rapidly eaten into the island to become 50 m wide. Rewakant Bora, a resident of Majuli, says, "If this goes unchecked, there is the danger of the island splitting into two."

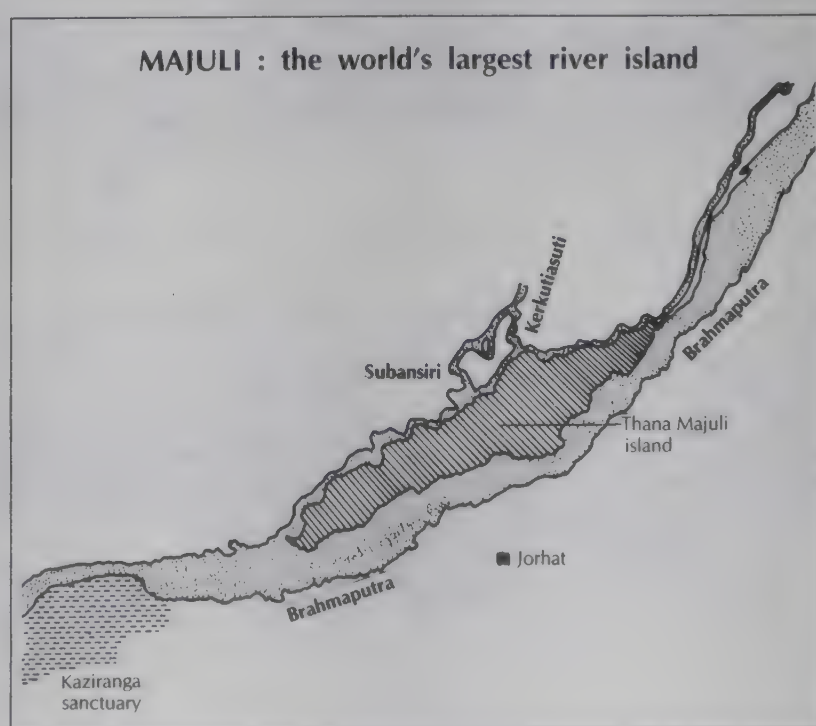
The local people also feel that floods are not only increasing, but their pattern is also changing. The severest floods now occur outside the traditional months of June to September.

Approach to the island normally is by an hour long ferry ride but during floods a long circuitous route has to be adopted. In 1987, Majuli faced its severest floods. More than 50,000 heads of cattle perished and crops were washed away. The prosperous island with a thriving dairy industry now has to import cattle.

The two successive flood waves disrupted life. The island was cut off from other places for about a month in two spells of a fortnight each. Once a seat of the Vaishnava cult and a centre for Assamese art and culture, Majuli now wears a look of melancholy with its economy shattered.

"It is only in the last three decades that the floods have become intolerable. The major floods of 1962, 1974 and 1980 were mostly due to the rise in the river bed. The eroded soil from the banks has gradually raised the level of the river bed over the years," says Niran Saikia, a resident of Majuli. The end result now is that most of Majuli, except the embankment protected area in the northeast, is prone to severe erosion. The Brahmaputra Flood Control Committee's (BFCC) assessment matches that of the local people. A BFCC report says, "Prior to the great earthquake of 1950, erosion in this area by Brahmaputra was not acute. The erosion became active thereafter and attained serious proportions after the flood of 1954." Since then the erosion has been continuing on both banks of the island.

How long will Majuli last ?



Both erosion and floods have been on the rise in the Brahmputra. Over one-third of Majuli island has been devoured by the river.

Table 37

Sediment production rates in the Brahmaputra basin

River	Source	Sediment Production Rate (t/ha/yr)
Brahmaputra (Pandu)	8.04	
Northern tributaries		
Jia-bharali	Himalaya	47.21
Puthimari	"	28.87
Buriaie	"	24.06
Pagladiya	"	18.83
Manas	"	15.81
Subansiri	"	9.59
Southern tributaries		
Dibang	"	37.65
Lohit	"	19.60
Burhi dihing	"	11.29
Desang	"	6.22
Dhansiri (south)	Naga-Patkai hills	3.79
Kopili	Cachar hills	2.30

Source : 92

Table 38

Bank erosion in the river Brahmaputra between Dibrugarh and Bessamara

Cross section of river	Width of cross section 1971 (km)	1981 (km)	Increases in the width of the river channel (km)
1	9.2	10.0	0.8
2	9.2	9.6	0.4
3	9.1	10.9	1.8
4	10.6	12.7	2.1
5	11.7	13.8	2.1
6	9.5	11.6	2.1
7	11.9	15.3	3.4
8	9.7	13.0	3.3
9	10.1	10.9	0.8
10	6.6	6.7	0.1

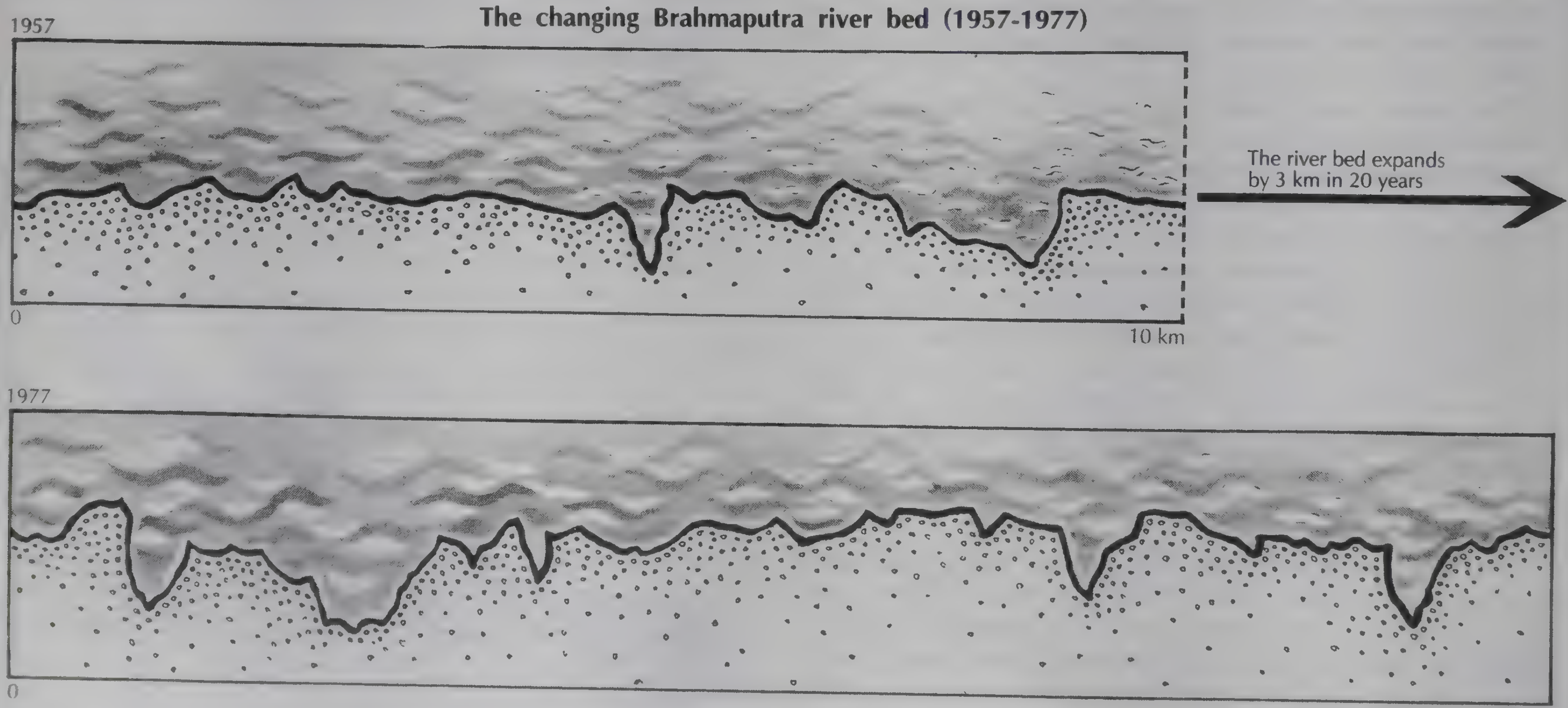
Source : 79

table 37)[103].

The bank line of the Brahmaputra is also extremely unstable consisting mostly of fine sand and silt. Large scale slumping of river banks takes place when the level falls after a flood. The width of the Brahmaputra is highly variable and can vary up to five km. From one year to another, these widths change dramatically. Between 1971 and 1981, the width of the river increased at all the ten cross sections that were studied, and in some cases, this was over three km (see table 38)[79].

The Brahmaputra has a tendency for a lateral shift towards the south because of the heavy silt charge of the northern tributaries[105]. The south bank is being more heavily eroded than the north bank[5]. Data collected by the Brahmaputra Flood Control Commission from 1954 to 1969 showed that some 253 villages and 8,091 hectares of land

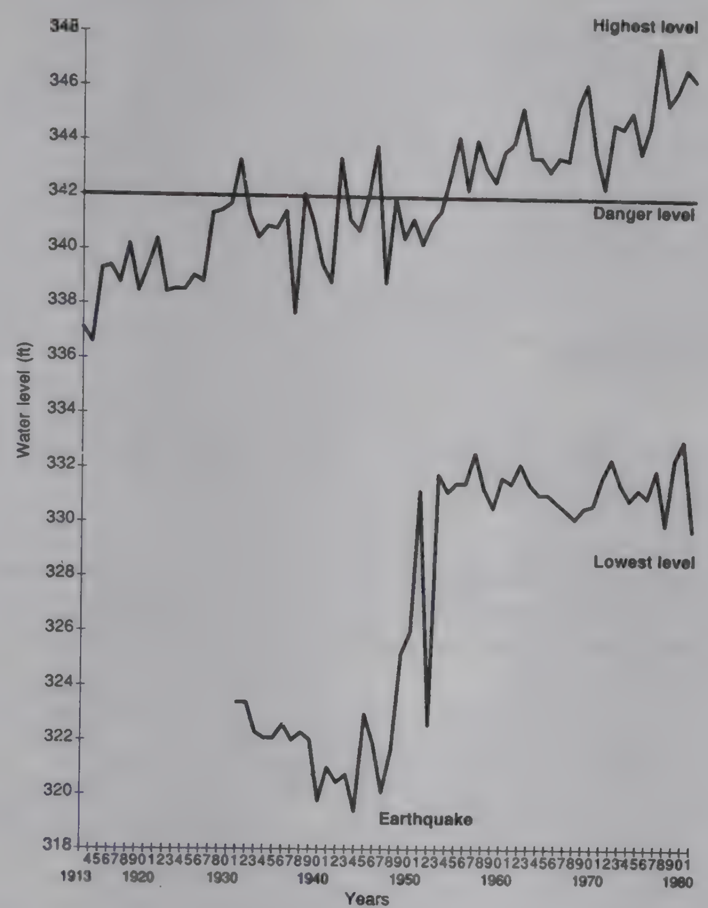
The changing Brahmaputra river bed (1957-1977)



Source : 79

The river bed and the bank line of the Brahmaputra is extremely unstable consisting mostly of fine sand and silt. Largescale slumping of river banks takes place when the level falls after a flood. The width of the Brahmaputra is highly variable. Between 1971 and 1981, the width of the river increased at all cross sections that were studied, in some cases this increase was over three km.

Highest and lowest flood levels of Brahmaputra at Dibrugarh before and after the 1950 earthquake



Source : 6

The 1950 earthquake had a tremendous effect upon the Brahmaputra's drainage, it brought in enormous amounts of sediment which raised the river's bed. Prior to it the Brahmaputra hardly ever flowed above the danger level at Dibrugarh. After this it has consistently flowed above the danger mark at Dibrugarh. Even the lowest water level at Dibrugarh rose by nearly 10 feet.

were annually affected by erosion. In other words, over this 15 year period, 1.53 per cent of the total land area of Assam was affected by bank erosion[106].

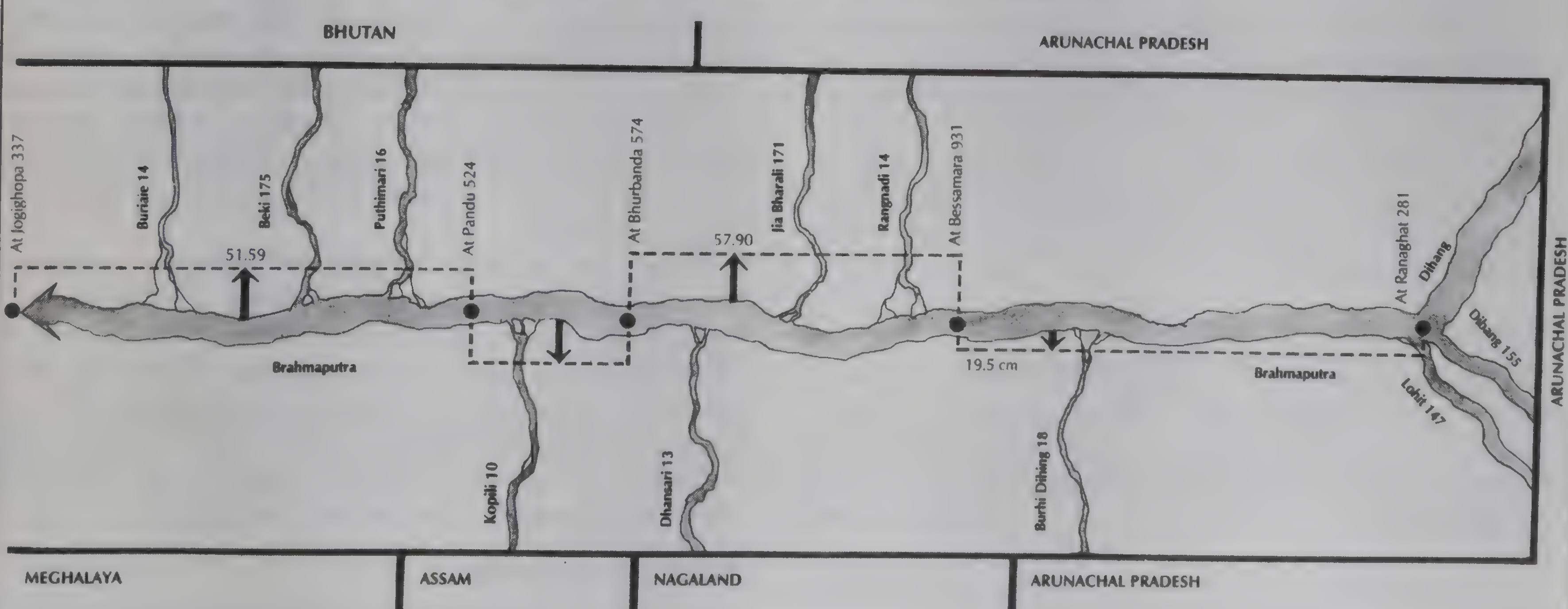
Goswami's study shows that between 1971 and 1979, 790 mcum of sediments, which is about 70 per cent of all the sediments brought into the Brahmaputra by itself and all its tributaries, got deposited over the 607 km stretch from Ranaghat to Jogighopa. The river bed from Bessamara to Bhurbandha and from Pandu to Jogighopa rose by 0.58 m and 0.52 m, respectively. Over other reaches, there was a slight fall.

The rate of sedimentation has also been varying. Data collected on the sediment quantities transported by the river from 1957 to 1977 shows that the river had very high rates from 1957 to 1960, moderately high rates from 1966 to 1969, and low rates from 1971 to 1976. The river bed from Kobo to Bessamara increased in height from 0.5 m to 2.4 m between 1957 and 1971 but from 1971 to 1977, the river bed actually dropped by 0.21 m, even though water flows did not change appreciably.

The increase in the height of river bed has influenced the high flood level. Between 1913 and 1978, the highest flood level has steadily gone up at the rate of 3.05 cm per year, or by 1.98 m in 65 years[5]. Prior to 1950, the Brahmaputra river would rarely exceed the danger level in the upper reaches of the valley. It exceeded the danger level at Dibrugarh only in 1931, 1938, 1942 and 1946 and the duration was only for two days. But since 1954, the river goes above the danger level every year more than once and the high floods above the danger level now last 16 to 20 days.

With the help of data from the four major rivers, Subansiri, Jia Bharali, Manas and Dihang, Goswami has

Annual sediment load of the Brahmputra (1971-79)



Source : 103

The Brahmaputra and its tributaries bring down enormous quantities of sediments which are deposited along the river creating sand bars. These sandbars move with changes in waterflow leading to changes in the height of the river bed in different places.

Note : Dotted line shows rise and fall of the river bed (in inch). Sediment contribution of minor tributaries not shown. Silt load figures in million cubic metres.

estimated that the average denudation rate of the Brahmaputra basin was 1.57 mm/yr between 1955 to 1979 but from 1971 to 1979, it was only 0.73 mm/yr. In other words, the period 1955-1971 had a much higher denudation rate. Between Tsela D'zong, which lies high up in the Himalayan mountains and Ranaghat, which lies in its foothills, the denudation rate is very high. Monsoon downpour heavily erodes the steep and friable slopes of the middle and lower Himalaya. The area suffers numerous landslides every year. During earthquakes, landslides take place on a massive scale.

The 1950 earthquake led to the accumulation of large quantities of sediments at various storage sites in the basin, including the river bed. But since the sediment yields from the hilly catchments went down in the 1970s the high water flows in the river have now begun to scour the river bed. This is why the height of the river bed from Kobo to Bessamara between 1971 and 1977 has actually dropped. As Goswami puts it, "there appear to be phases of rapid aggradation of the river bed associated with earthquakes followed by periods of relatively slower removal." Available data, therefore, shows that the 1950 earthquake has played a major role in the morphology of the river.

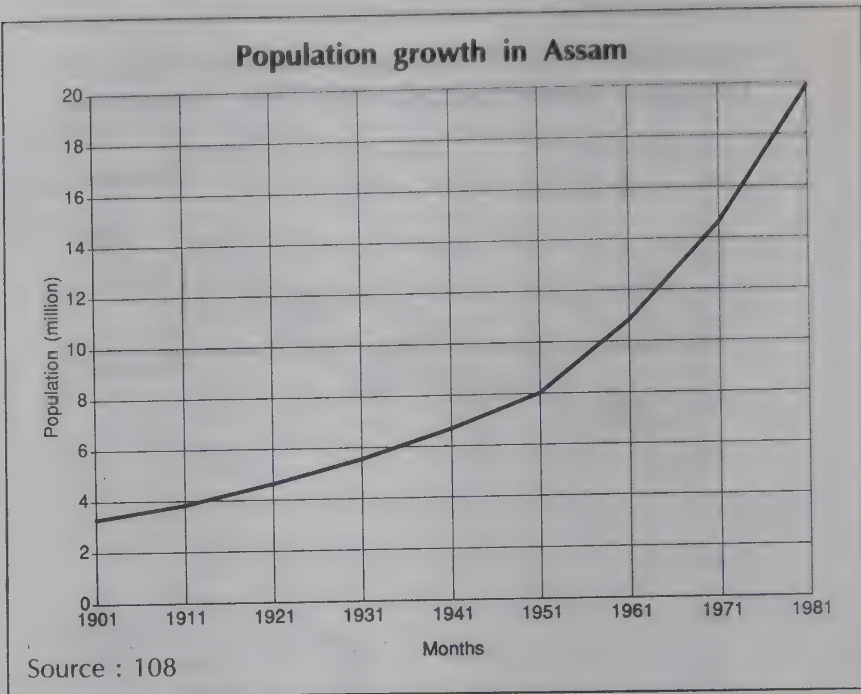
Deforestation and shifting cultivation on the steep slopes and valley bottoms have definitely contributed to the high erosion rates in the upper reaches of the river and its tributaries. Shifting cultivation is practiced intensively in most of the hills in Meghalaya, north Cachar hills, Nagaland, Manipur and Mizoram. Soil loss increases with deforestation and construction activities which ultimately chokes the waterways downstream, especially when they are embanked in the valleys. But there is limited data to evaluate the contribution of such anthropogenic factors, according to Goswami, who himself believes that natural factors play a more significant role.

Recurring earthquakes seem to have a pronounced effect upon river channels. The sediment yield beyond Bessamara declines rapidly even though water yields continue to go up. This is because of the increasing distance from the zone of maximum sediment supply between Ranaghat and Bessamara and because both the slopes and annual precipitation begin to decline. Northern tributaries which come from more forested areas cause more flood problems than southern tributaries.

Human occupation of flood plains

While scientific studies do show that floods are inherent to the ecological setting of the Northeast and human beings can do precious little to prevent or control them, there is no doubt that unthinking human intervention has increased the vulnerability of the Assamese society to floods over the years.

The Brahmaputra flows through extremely fertile alluvial plains once it leaves the hills. Forests now cover only a few places along the foothills. Most of the high land is occupied by tea gardens. The lower portion of the narrow valley is occupied by thousands of villages and cultivated fields. Since the rich are more involved with tea gardens, the floods affect the poor more who occupy the lowlands.



The population of Assam has risen from slightly more than three million at the beginning of the century to an estimated 20 million by 1981. The result has been a steady encroachment of the flood plains.

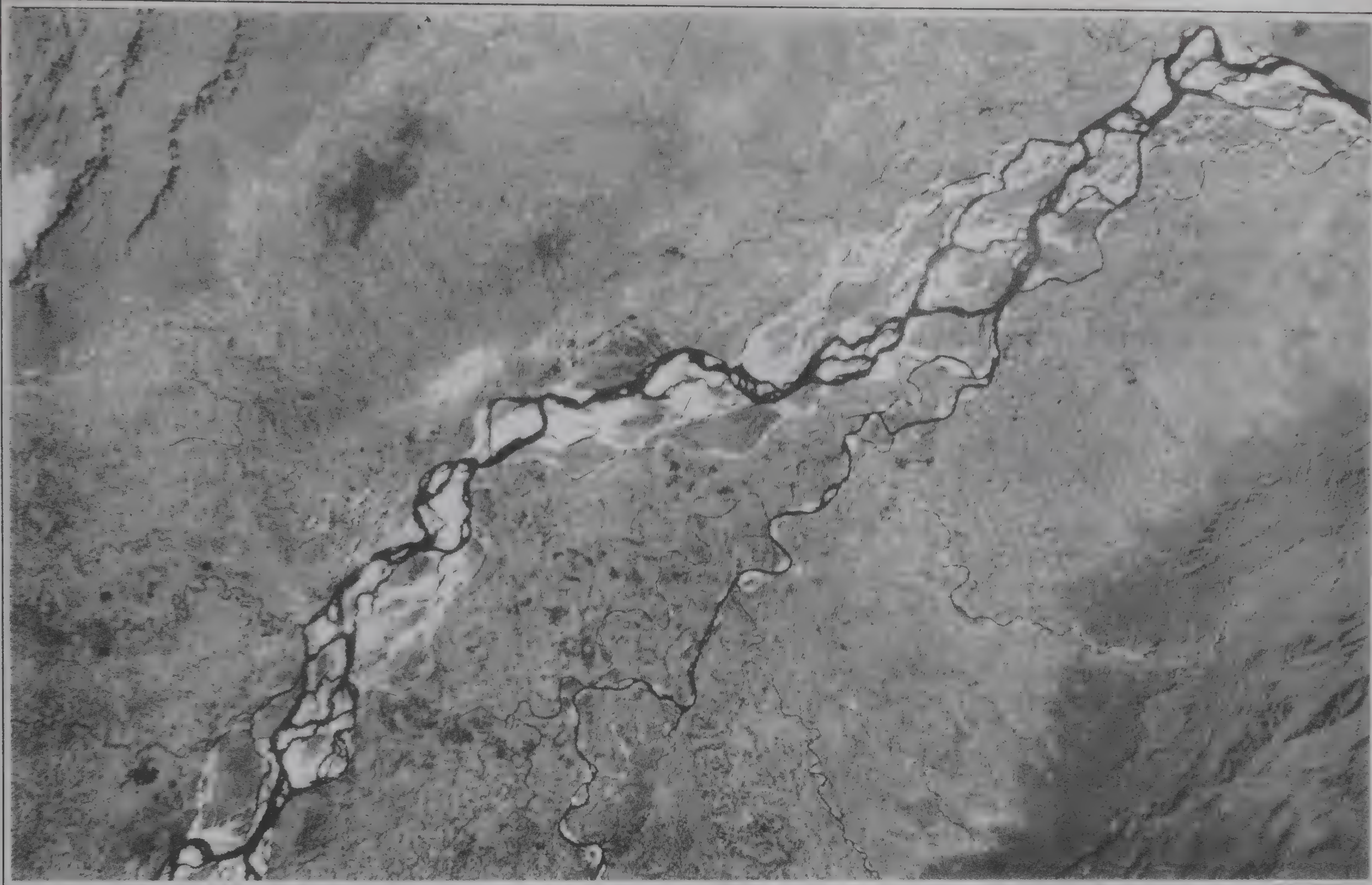
Four types of lands are found along Brahmaputra. The banks of the river are called *chapris,* which are made of the fertile silt brought down by the river. Adjoining this land are the low lying areas in which bao paddy — a variety grown in flooded areas and also known as deep water rice — is grown. Bao is deep water broadcast variety. It is sown in March or April and harvested in November or December. These low lying riverine areas are called *bils.* They are abandoned river beds and get inundated every year. Water enters during high floods and a few feet of it stagnates for the rest of the year. Above the bils are the fertile alluvial plains in which hundreds of varieties of paddy are grown. The hilly tracts rise immediately after the alluvial plains, where most of the tea gardens are situated[107].

Population has been growing rapidly in the plains. It increased from 3.29 million in 1901 to 19.9 million in 1981[108]. This steep rise has forced the people to encroach riverine areas resulting in constricted waterways, increased sedimentation and, in turn, floods of higher intensity. Abandoned channels and horseshoe lakes which would otherwise absorb, at least, the initial impact of floods, have been reclaimed[93].

Flood control measures like embankments undertaken immediately after independence, bred a false sense of security which tempted people to encroach deeper into the flood plains and into the riverine areas. After 1954, when the government started building embankments, the area fortunately did not experience high floods for nearly two decades. But now when these measures are failing, the damages to property and life are very high[109].

Wetlands destruction

The worst destruction has been that of bils. Several are found in the districts of Lakhimpur, Nagaon, Kamrup and Goalpara. Their ecological role is only now being appreciated by scientists. The fact that the bils predominate the flood plains is an indication of the important role they play in the hydrology of the river. Unfortunately, data on the



THE DRAGON'S VALE : A satellite picture showing the wide river bed of the Brahmaputra with enormous sand islands. The river bed occupies a large part of the narrow Assam valley. (NRSA)

extent of bils is extremely unreliable.

The Rashtriya Barh Ayog's report in 1980 estimated the area under bils at 49,000 ha[5]. But a more recent survey has noted that there are approximately 1,600 such water bodies which cover an area of 35,630 ha[110]. The largest is the Sone bil in the Barak valley. It has a minimum area of 400 ha during winter months and approximately 3,500 ha during the monsoons[111]. The Assam Bil Fisheries Development Corporation set up in 1970, estimates the bil areas to be about 100,000 mha.

Table 39

Bils in Nagaon district

Size of bil (ha)	Number of bils
50 and above	7
40-50	11
30-40	5
20-30	37
10-20	31
1-10	117
Less than 1	46
	254

Source : 110

Surveys carried out by Guwahati university point out that these wetlands are today in a derelict or semi-derelict condition with high rates of siltation, infestation of weeds like water hyacinth, and human interference for agricultural, settlement and industrial purposes.

Wetlands in general have been neglected. There is a danger that even before their ecological role in Assam is fully understood, they may be lost. Bils are periodically fed and drained by the rivers. When the Brahmaputra or its tributaries overflow, the excess water flows into the bils. They, thus, act as sponges to hold the excess water[110]. This possibly helped to reduce the intensity of floods in the region

Table 40

Effect of flood control measures on fish productivity of bils

Name of bil	Flood control measures	Fish yield (kg/ha/yr)
Bormonoha	None	240-345
Sibasthan-Putakolong	Bil inlet channel blocked by an embankment	5-9
Morikolong-Putakolong	Bil inlet channel blocked by an embankment	6-18

Source : 110

SWAMPED ISSUES

Guwahati's environmentalists are finding that protecting a swamp from the depredations of developers is not an easy task. At stake is the Deepar *bil* a major wetland which absorbs the city's storm water during the monsoon season. Situated near Guwahati, the bil is a natural habitat for a sizeable number of birds and wildlife. The Northeast Frontier Railway (NFR), however, wants to lay a broad gauge railway track through it[1].

Deepar bil, according to Assam's town and country planning department, has a surface area of about 1,010 ha, nearly twice that of the famous Bharatpur bird sanctuary[2]. The exact expanse of the bil eludes most estimates. While the flood control department puts it at 5,489 ha, the fisheries department insists it is only 440 ha. However, Landsat pictures show the bil's area to be 1,600 ha in the summer, swelling to 1,800 ha in the monsoon. The bil is a habitat for 122 bird species in the cold season and conservationists claim that as many as 7,000 birds have been counted in it on a single day. A number of educational and training institutions use it for research on wildlife and birds.

Some 414 ha of the bil was declared a wildlife sanctuary by the Assam government in 1989. Yet even six months later, the NFR was planning to build railway tracks through the bil. The chief conservator of forests argued against the plan[2]. NFR suspended its work on this stretch but continued work on the other stretches of the proposed railway line.

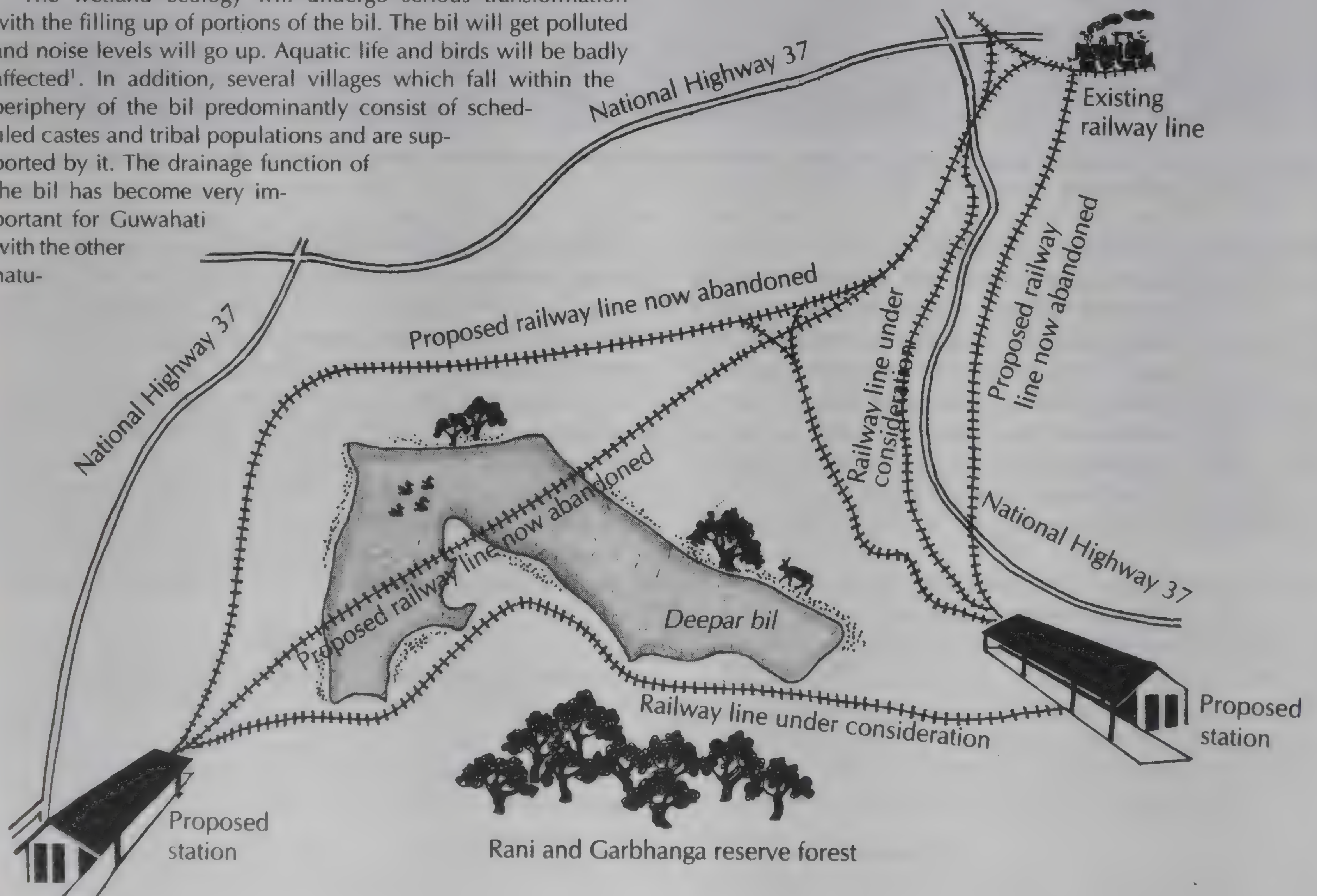
The wetland ecology will undergo serious transformation with the filling up of portions of the bil. The bil will get polluted and noise levels will go up. Aquatic life and birds will be badly affected[1]. In addition, several villages which fall within the periphery of the bil predominantly consist of scheduled castes and tribal populations and are supported by it. The drainage function of the bil has become very important for Guwahati with the other natural channel for the city's storm water, the Bharalu river, getting choked and extensively encroached upon[2].

The bil acts as a temporary reservoir for storm water from the city and the adjoining hills of Meghalaya. This water gets ultimately drained into the Brahmaputra through the Khana river by a sluice gate[4].

Conservation of the bil threatens numerous vested interests — stone quarry owners, brick kilns, and garages and motor workshops, situated along the Guwahati-Shillong national highway[2]. The highway was laid out 20 years ago on the eastern fringe of the bil and has encouraged numerous encroachments into it.

Vocal opposition to the building of the rail tracks has come from eminent experts, including the principal of the Assam Engineering College, A K Padmapati. The local Institute for Scientific and Technological Research (INSTER) submitted a memorandum to the government to preserve the bil. INSTER's general secretary, Achintya Bezbaruah has maintained that the proposed construction would affect not only the bil but also the ecosystem of Guwahati[3,5].

The government of Assam has formed a committee to study the environmental issues connected with the bil and to suggest an alternative to the broad gauge line. But the committee has been taking a long time to submit its report[2].



Source : 1

The Deepar bil is a natural drainage point for the storm waters that flood Guwahati. The role of the bil is now even more important because the other natural channel, the Bharalu river is choked and hopelessly encroached upon. Destruction of the bil by a railway line will have grave consequences for Guwahati city.

in earlier times. Moreover, when water flowed in from the river, it helped to increase the productivity of the wetlands (see table 40). The incoming water brought with it fry and fingerlings of fishes and other aquatic organisms. Some fishes would breed only in these bils and would move back into the main river as the flood waters receded. Thus, thousands of fisherfolk depended on the bils. The jacketing of the Brahmaputra within embankments has also affected the autostocking of the river as carp and other varieties cannot laterally migrate into still waters to spawn.

A study by Abhik Gupta of St Edmund's College, Shillong shows that many of the bils in Barak valley are getting silted up rapidly and getting converted into croplands[111]. Large scale deforestation in the hill areas of Mizoram, Manipur, Meghalaya and north Cachar, which form the watershed of Barak and its tributaries, seems to be increasing the siltation rate. Brick and cement block manufacturing units in the Barak valley are contributing to soil erosion. Pollution is yet another factor affecting the bils now. Bils have also disappeared because their inlet channels have been blocked by embankments. This has greatly reduced fish production from these bils[110].

Most experts are in favour of preserving the bils. The Rashtriya Barh Ayog in 1980 strongly recommended against their reclamation[5]. It argued that such low lying areas should be put under fish production by constructing ponds in marginal areas and constructing sluices at the mouth of the channels so that water could be let in during floods. The report clearly stated, "In consideration of the importance of retaining valley storage for flood moderation, no large scale drainage scheme of reclamation of bils, *chaurs* or *jheels* should be taken up without considering their other alternative uses for fishery, irrigation, biological sanctuary for tourists and the like" [5].

Most bils in Assam (both oxbow and lake types) are registered with the revenue department except for those which are in forest areas. There is no free fishing in the bil as the revenue department auctions them for two to five years at a time. These leases are in turn sublet and tributary streams are often fragmented into separate holdings with bamboo screens erected by lessors to maximise their catch. The result is slaughter fishing. The Assam Bil Fisheries Development Corporation advocates leasing out the bils to fisherfolks cooperatives on a long term basis and interconnecting them back to the spawn bearing riverine waters and their subsequent flushing with flood waters[111a].

The expert committee on 1986 Assam floods has also pointed out that "the *haors* in Silchar district — natural depressions which lie close to the river — and bils in the Brahmaputra valley used to moderate floods to a great extent. Deforestation in the upper reaches of the rivers has caused siltation of the haors and bils. Due to encroachment by the settlers, there is no moderation of flood now." The expert committee strongly criticised the policy to encourage unrestricted settlement in the riverine areas as well as in the meander belt of the rivers. Settlement in riverine areas is extensive in Nagaon and Jorhat in the Brahmaputra valley and Cachar and Karimganj in the Barak valley.

Since there is no settlement policy, people get into all kinds of self-destructive situations. Villagers displaced by floods often encroach on forested lands leading to deforestation. All this often happens with the encouragement of the government. In the Doom Dooma forest division near Tinsukia, flood displaced villagers felled a large number of trees in 1989 to occupy the area[112]. The 1986 expert committee pointed out that in several areas where encroachments in forests are strongly restricted, people encroach upon the partially sedimented wetlands, whereas neither wetlands nor forests should be encroached upon. "This situation is responsible for increasing the flood peak in all rivers and is likely to aggravate if no restriction is imposed on the open settlement in riverine areas," the committee warned[93].

Sanjay Deb Roy, chief conservator of forests in Assam points out that the destruction of the terai swamps is another cause of increasing floods. As he puts it, "The terai swamps with their natural reed beds and various other vegetative components had been acting as a natural barrier to floods during the monsoon and serving as a water reservoir during the dry period, when the water was gradually released along the numerous streams and *nullahs*. This maintained the water table at an optimum level right round the year, which held the productivity gradient at a steady level. But with the conversion of the terai region into agricultural areas, the water retention capacity of such highly complex ecosystems was lost in a few years and flash floods started appearing"[113]. There can be no doubt that ecologically appropriate policies for human settlement, agriculture in the flood plains and protection of wetlands are urgently required in Assam.

Embankments

Some 200 km of embankment was constructed between 1947 and 1954 in Assam[5]. By 1988, the government had built a total of about 4,000 km of embankments on the rivers[92]. Inspite of such an extensive network, the problem of floods has increased year after year. In 1987 and 1988 nearly all the area protected by embankments was affected by floods because of breaches in them (see table 41). In fact, the popular belief in Assam today is that embankments themselves have become a major factor for causing floods and people would be much better off without them[106].

There is no doubt that embankments have created numerous problems. Himalayan rivers have more or less

Table 41

Flood protected area affected by breaches in embankments

Year	Area protected	Area affected due to breaches in embankments		Area restored through protection measures
		Actual	% of total	
	(mha)	(mha)	(%)	(mha)
1985-86	1.33	0.27	20	1.33
1986-87	1.36	0.25	18	1.36
1987-88	1.40	1.35	96	1.40
1988-89	1.43	1.38	97	1.43

Source: 123

UNSAFE SANCTUARY

Will the one horned rhinoceros of India like the unicorn become the stuff of myth and legend or will the very sanctuary that gives it shelter go under the Brahmaputra?

Situated 200 km from Guwahati is the Kaziranga National Park, the largest unspoilt area of the flood plain of Brahmaputra, which forms its northern boundary. Permanent wetlands comprise six per cent of the park area and the river seasonally inundates grasslands covering 66 per cent of the sanctuary. The national highway 37 cuts through the lower edge of the park from northeast to southwest[1].

While annual flooding has saved the park area from human settlement, it is nevertheless bounded by cultivation and settlement on three sides. Within its confines, now struggling for survival, is the rhinoceros *(Rhinoceros unicornis).*

In a park area of 42,996 ha, the rhino rubs shoulders with 14 other threatened mammal species of India. A plan to populate another sanctuary like Dudhwa with rhinoceros was a miserable failure and a major setback for naturalists. Thankfully the interplay of floods and fire has more or less preserved Kaziranga in its present form for thousands of years.

Lack of a buffer zone around the park has led to conflict over illegal grazing by domestic livestock and crop raiding by animals. The Brahmaputra is gradually eroding a portion of the northern boundary of the sanctuary and traffic on the national highway 37 is increasing. The greatest threat is the proposed railway line running parallel to the highway.

In 1988, severe floods ravaged Kaziranga and claimed the lives of over 85 rhinos. The floods also destroyed buildings, raised platforms, bridges and roads inside the park. Heavy erosion by the Vengai river uprooted huge trees. Consequently, wildlife was forced to flee to the adjoining Karbi Anglong district through the highway.

The four successive waves of floods which hit the Brahmaputra valley in August 1988 were unprecedented. Normally, the river floods 70 per cent to 80 per cent of the park every year. However, with large scale embankments and resultant raising of the river bed, flood levels have risen with alarming frequency. So much so that animals found the higher reaches where they normally used to shelter also submerged.

The 1987 high flood level surpassed previous records by 25 cm. In 1988, it exceeded the previous year's level by 50 cm. Many calves and older animals, forced to swim for safety, perished in the process. Another reason for high casualties was starvation as female rhinos refused to leave their refuge for fear that their calves would follow and be drowned[2]. In other years, this problem had not existed as flood waters receded within a few days. But human interventions like roads, embankments and reclamation of depressions for agriculture in the state have given rise to the problem of prolonged waterlogging.

The state's reaction to the resentful Brahmaputra's fury has again been in the form of engineering responses. Bureaucratic red tape is now loaded with the blueprint of a Rs 20 crore plan to create high platforms in the park, and increase the level of the east-west road in the central region to prevent its inundation[3].

The Brahmaputra dyke from the starting point of the national park to Diphalupather has been both raised and strengthened. The message of the 1988 flood and the mounting evidence against the false sense of security imparted by embankments have both been ignored. Is it then that the destiny of the Assam rhinoceros is to follow the precedent of the dinosaurs and the dodo?

ENDANGERED : A rhino pair strolls in the grasslands in Kaziranga, a sanctuary endangered by the Brahmaputra. (Anil Agarwal/CSE)

similar characteristics while passing through the alluvial plains. As elsewhere in the country, they shift their courses because of erodible banks and a heavy silt charge[93].

The 1986 Assam floods expert committee has aptly brought out the problems. The report states that the high silt loads carried by the rivers and the changed land drainage patterns in the flood plains together create conditions of excess flood flow. Denudation in the uplands has also increased the overland flow of rain water. The high silt loads result in choked river channels. Embankments aid in aggrading the river beds. Silt which used to be deposited in the plains, now drops inside the river channel. The land drainage pattern has changed drastically because almost all streams are now guarded by marginal embankments. As major rivers like Brahmaputra and Barak have also been heavily embanked, the rain water in the valley, which falls outside the embankments, accumulates and forms stagnant water bodies, particularly near the confluence of the tributaries and the main rivers. Improper operation of the sluices in the river embankments delays the drainage process and flood waters stagnate and prolong human misery. Embankments cause drainage congestion because even after the flood water has receded, water in the surrounding areas does not have an outlet. The sluices provided in the embankments are of no use because people living downstream object to their being opened. Enormous tension develops at the sluice gates during high flood levels. This results in prolonged flood conditions upstream[93]. For all these reasons, the committee strongly felt "that the embankments have changed the behaviour of the Assam rivers towards the worst. *No more embankments should be constructed to avoid a deterioration of the situation*"[93].

The 1986 expert committee lamented the fact that the Brahmaputra has not been studied adequately and yet extensive flood control measures like embankments have been undertaken. An internal note of the Assam government also states, " The embankments constructed have served a useful purpose in protecting areas from floods but all the same they have been found to be inadequate as most of the embankments constructed prior to 1970 were based on insufficient hydrological data. This has resulted in a large number of breaches occurring every year"[105].

The 1986 committee points out that with embankments being built on the river since 1954, and high floods having disappeared for nearly two decades, scientists became too complacent to study the river. But the very measures taken to prevent the floods, have stopped the sediments from moving out of the streams. Effective slopes have, therefore, decreased and relative height between the valley and the river beds has decreased. This has created larger floods every year. Many river beds have shown an abnormal rise. Yet few records are available on the aggradation pattern of the rivers. Rainfall and soil studies are also lacking. An insignificant number of automatic rain gauges exist. The report states firmly that such studies are required immediately, otherwise flood control measures like embankments will play havoc in Assam[93].

A newspaper report points out that the popular view in Assam is also that embankments cause more problems rather than mitigate them. As water gets trapped behind the embankments during floods, the government, apart from providing relief to the people who take shelter on the embankments, also has to ensure that they do not breach the embankment to release the accumulated water from their lands. The consequence of such a step would be the flooding of even larger areas of land on the other side. Police patrolling is done regularly on two embankments in Assam. One is the embankment along the Killing, Kopili and Kolong rivers and the other is the embankment protecting Dibrugarh town. A special task force for patrolling and protecting embankments is being trained. Constant vigil is necessary to prevent desperate villagers from damaging the embankment to release water from inundated villages[106]. It was the deliberate cutting of the embankment at Boijurai, according to G Biswas of G C College in Silchar, which inundated the entire town in 1986[93].

The Rashtriya Barh Ayog has also warned that "the aggradation of the river caused due to the construction of an embankment, poses a threat to the safety of the embankment. On account of the progressive rise in the bed levels, the high flood levels go on increasing and exceed those of the previous years for the same discharge, with the result that, if the embankment has to continue to give the same degree of protection as initially designed, its progressive raising becomes inevitable."

The Ayog grimly warned, "If so, a stage may come when it may no longer be possible to contain the river by the embankment. Also, if a breach were to occur under such circumstances, there is not only the danger of greater devastation but also the possibility of an evulsion of the river into a new channel." If that channel is already occupied for cultivation and by settlements because of the population pressure on the flood plains, the resulting human misery can be well imagined.

The RBA report also points out that when the water level in the river even in the dry weather will become higher than the surrounding countryside because of the aggrading river bed, continuous seepage will take place round the year through the embankment and the subsoil beneath the embankment. This will cause extensive waterlogging in neighbouring areas. The 1986 committee mentions that the bed of Longai is now higher than the surrounding countryside[93].

Apart from river embankments, railway and road embankments have also seriously hampered and changed the drainage pattern in the state. Openings in roads and railway bridges and culverts are often inadequate. Newspaper readers normally hear of floods washing away roads and railway lines, thus, leaving flood affected areas without outside help. But few know that often these roads and railways themselves cause floods.

The RBA noted that there are four narrow railway bridges on the Puthimari river which frequently cause floods upstream. When the flood waters of a swollen river encounter a narrow bridge, the water level upstream rises and can overflow and breach the embankment upstream. There are two points on the Pagladiya river which experience a similar problem frequently. The 1986 report

points out that river, road and rail embankments have together created serious drainage congestion in Nagaon district[93].

The natural drainage system and the rail and road network are almost at right angles to each other in the Brahmaputra valley. While all tributaries flow in the north south direction, the railways and roads have been built in the east west direction. As it is not possible to develop them otherwise, the government has to be extra careful. But waterlogging is now a common feature in many areas during large parts of the year.

WAYS AHEAD

In a memorandum to then Prime Minister Rajiv Gandhi in 1988, chief minister Prafulla Kumar Mahanta said, "there is absolutely no doubt that floods will again devastate Assam in the coming years. Recurrent floods have already broken the backbone of Assam's economy. A committee of experts should be appointed to find a permanent solution to the problem" [114]. No doubt everyone in Assam would love to have a flood free state.

Numerous solutions have been proposed from dredging the river bed and construction of dams and embankments to preserving the ecology and learning to live with floods. While the first calls for major technological interventions, the latter essentially pleads for a greater concern for the ecological balance in the area and developing lifestyles and production systems that are in harmony with the local ecology. Since 1929 at least 10 flood inquiry committees had been constituted[109]. In 1947, a committee headed by S C Mazumdar of Central Water, Irrigation and Navigation Commission had opposed further construction of embankments, recommended the gradual removal of existing ones and construction of multipurpose dams[109]. After independence, a flood control and irrigation department was set up by the state government. Subsequently, this was bifurcated by creating the Brahmaputra Flood Control Commission (BFCC) and it was decided that the flood control work in the Brahmaputra valley will be financed by the Centre. In 1981, the BFCC was dissolved to set up the Brahmaputra Board for the preparation of a flood control master plan for the entire Northeast. The board submitted two master plans in 1986 and 1988, which relate to the main stem of the Brahmaputra and the Barak. These are to be followed by another report on the tributary streams[111a].

The board's master plans envisage the setting up of water flow, meteorological and earthquake recording stations, modernisation of flood forecasting equipment, anti-erosion schemes, jhum control, new drainage networks and multipurpose dams. Their estimated cost in 1983 was put at Rs 82,045 crore and Rs 23,840 crore beyond 2000 AD[114].

Dredging

The river channel can be theoretically improved by deepening the bed and removing obstacles such as rocks and boulders through an extremely expensive method in which heavy equipment is involved. Even though it is a controversial solution, dredging of the river Brahmaputra was suggested by a number of experts during the 1950s and the early 1960s. The Government of India, therefore after much ado, decided to undertake the efforts to dredge the Brahmaputra on an experimental basis in 1966. The efforts largely failed.

Preliminary studies were made about the river bed and its hydrology. The first operation was undertaken in 1974 at Chimna in Kamrup district, to save the embankment in the area. Instead of an envisaged stretch of 12 km, only a stretch of seven km (with a width of 30 m) could be dredged. The work was completed by mid-June, 1975. The second operation was conducted at Alikash, 15 km downstream of Chimna, to reduce the erosion of the Alikash bank. The operations started towards the end of 1975 and the floods of 1976 revealed that the erosive activity on the river bank had diminished.

Both operations were considered failures. The two experiments showed that dredging prevented bank erosion but the Brahmaputra river bed changes so rapidly that the dredged areas soon get silted up again. Therefore, 'maintenance dredging' would have to be taken up every year. T N Barman of Assam's flood control department calculated that to dredge a length of one km, at least two dredgers of 500 cu m/hr capacity would be required for six months. The number needed for the entire length of Brahmaputra, or even its chronically flood prone parts, would be phenomenal. Moreover, for dredging to be successful, civil works would have to be undertaken to train the river to flow through the dredged area.

Barman also highlighted the environmental effects of dredging operations. Since dredging will be a repetitive process, huge quantities of materials would have to be removed every year and placed along the river banks or carried to remote places. Disposal of dredged materials on such a large scale would definitely have an adverse impact on forests, wildlife and cultivated areas. Secondly, dredging will affect aquatic organisms within the river. Barman felt that dredging could also have an adverse impact on downstream areas, where river flow patterns can change.

Barman, therefore, did not recommend dredging unless measures like soil conservation and watershed improvement were also undertaken. And, even then it should be a part of a package of measures which include the training of the river to flow through a predetermined channel and undertaking civil works to armour the bank against erosion[116]. All this is prohibitively expensive and few people in Assam now talk of the need for dredging.

Dams

Many experts believe that the ultimate solution lies in the construction of dams in the mountains to store the water and the silt brought down by these massive rivers. The Brahmaputra Board strongly believes in the need to construct dams. Every time floods come, the state government raises the issue of dams. The present AGP government of Assam has been pressurising the Central government to commission the Subansiri and the Dihang dams in Arunachal Pradesh, which have been recommended by the Brahmaputra Board. Apart from controlling floods, these

dams would also generate enough hydel power to meet the energy requirements of all the northeastern states. Engineers who have studied the local situation argue that the Dihang, Dibang and Lohit together contribute 50 per cent of the average annual flow into the Brahmaputra, while the Subansiri contributes 10 per cent (see table 32).

Storage reservoirs on these rivers would reduce the total flow into the Brahmaputra and, thus, moderate floods. Apart from the major tributaries, engineering experts also call for the control of 22 other tributaries of the Brahmaputra. The initial focus has been on seven tributaries — Dihang, Subansiri, Debang, Lohit, Manas, Sonkosh and Teesta[117].

The first two dams in the Brahmaputra valley have been proposed on Dihang and Subansiri, which will have a storage capacity of 35,500 and 10,600 mcum, respectively. Studies indicate that the Dihang dam will reduce the flood height at Pandu by 0.60 m to 1.75 m. The Subansiri dam would bring further reductions of 0.40 m to 0.15 m (see table 42)[117]. Another dam has been proposed at Tipaimukh to protect the Cachar plains.

Journalist B G Verghese in his book *Waters of Hope* points out that the Brahmaputra Board's reports are under examination by the member states and the Central government. Another point of view amongst the engineers looking at the proposals is that the cost-benefit ratios purely in terms of flood control will be even better if an alternative approach is adopted " keeping in mind that Dihang has a high base flow and a relatively low ratio of peak flow to this base discharge, a series of check dams on a number of smaller but destructive tributaries like the Pagladiya is advocated before embarking on major mainstream dams. These would give fairly early cost-effective flood cushioning

BARAK'S FURY

The Barak valley consists of Cachar and Karimganj districts of Assam. Constituting a separate watershed from that of the Brahmaputra, it is bound by the north Cachar hills in the north, Manipur plateau in the east and Mizo hills in the south, and opens on to the plains of Bangladesh in the west. The Barak and its tributaries, Sonai, Rukini, Katakhal, Kushiara, Singla and Longai, come down mostly from Manipur and Mizoram hills. The Barak itself rises in Nagaland and flows through Manipur before it enters the Cachar district at Lakhipur. The Barak river and its tributaries constantly change course. They carry a heavy silt load because of both geological factors and deforestation in the hilly catchment areas.

Each decade sees two to five major floods. The flood of 1929 are supposed to be the worst in memory. But the 1989 floods have been unprecedented in terms of the damages they have caused. The floods of 1985 and 1986 were also very bad.

The expert committee set up to study the 1986 floods in Assam pointed out that "the duration of floods in the Barak valley prior to 1950 was much shorter and the damage was not very high. But after 1950, the duration increased and the resulting damage also increased considerably." The committee claimed that even though well maintained embankments now cover nearly the whole length of the rivers in the Barak valley, the intensity of floods seems to be increasing every year. The Barak touched a high flood level of 22.03 m in 1989, well above those of 1985 and 1986, 21.45 m and 21.77 m, respectively. The 1989 flood level is second only to that of 1929 — 22.89 m — in recorded history[1].

G Biswas of G C College in Silchar told the expert committee that Silchar cannot be saved from floods by merely building embankments. According to him, the river bed has been rising, though this is disputed by the flood control department, and for the same discharge, higher and higher flood levels are being observed. The public attribute heavy siltation in the Barak valley to the rubber plantations in Manipur and heavy deforestation in Mizoram and north Cachar hills. The earthquake at Silchar in 1984 has probably also had an effect on the silt discharge of the Barak river. Biswas argues that there is no natural storage of flood waters now. Firstly, because of deforestation in the catchment areas. Secondly, because natural depressions in the valley areas are getting silted up rapidly or getting reclaimed.

Guwahati university geographer D C Goswami, who was a member of the expert group, points out that floods are mainly caused by drainage congestion. The river has a very flat gradient in the section where it traverses the narrow valley. At places the bed of the river now lies at elevations higher than the surrounding valley[2]. The valley is dotted with depressions locally known as *haors*. These used to serve as natural detention reservoirs. However, large scale encroachment of these areas in recent years has greatly impaired their drainage ability. The situation aggravates during high flood stages, when the Barak backs up into the tributaries and the flood spills fill up the haors leaving little dry land in the valley. In Silchar, several old bridges have also caused drainage congestion and backwater flows which inundate areas upstream.

A heavy downpour in the hills, thus, brings water gushing down into a valley primed for disaster. In 1989, the problem was compounded by a simultaneous torrential downpour in Manipur, Mizoram and north Cachar hills, which swelled the Barak and most of its tributaries like Katakhal, Madhuna and Jatinga, all at the same time. As the rivers rose, several embankments gave way. The deluge that engulfed Silchar was mainly due to breaches in a PWD road acting as an embankment which badly needed raising and maintenance[1]. Most people now believe that only a dam on theBarak river as it emerges from the hills in Manipur at Tipaimukh can save them from floods[1,3,4].

High flood levels in 1986 and 1989 in the Barak valley

River	Location	High Flood Level		
		1986 (m)	1989 (m)	Difference (m)
Barak	Annapurna Ghat	21.77	22.03	0.26
Barak	Chotobakra	30.40	32.10	1.70
Barak	Lakhipur	26.47	26.96	0.49
Sonai	Amraghat	28.61	29.99	1.38
Rukini	Dholai	27.30	27.75	0.45
Katakhal	Gharmoora	34.21	36.30	2.09
Katakhal	Matijuri	22.30	22.34	0.04

Source : 1

Table 42

Major dams in the Brahmaputra basin

	Dihang dam	Subansiri dam
Height (m)	296	267
Live storage (mcum)	35,500	10,600
Water spread at full reservoir level (ha)	NA	19,300
Installed capacity (mw)	20,000	4,800
Firm power (mw) (90 per cent dependability)	6,370	1,789
Cost (Rs crore)	8,600(1983)	3,068(1984)
Completion period (years)	13	10
Displacement		
Population	35,000	7,500
Villages	91	26
Towns	3	1
Submergence		
Total area (ha)	49,000	NA
Forest area (ha)	37,700	15,000

Source: 117

with 200-400 mw of power at each storage[111a].

The upland government of Arunachal Pradesh has, however, protested against these proposed dams as they would submerge huge tracts of forests, flat valley lands and towns and villages[118]. Environmentalists have also voiced their concern. The Northeast is seismic and damming such large quantities of water may give rise to reservoir induced seismicity. Earthquakes have occurred in the region. A major dam burst could wipe out large parts of the Brahmaputra valley[104]. The Brahmaputra Board, however, believes that dams can be built even in areas with such severe seismicity. It points out in its master plan," The advisability of building high dams in this region which is prone to severe earthquakes has been under serious consideration and several experts of international repute, both Indian and foreign, have been consulted. Their advice has been that safe high dams can be constructed at suitable sites provided allowance is made for the seismic factor in designing the structures[111a].

The need to construct the Dihang and Subansiri dams urgently was pointed out by the AGP government to then Prime Minister Rajiv Gandhi in 1988. The Assam government is strongly of the opinion that dams are the only long term and permanent solution to floods. Rajiv Gandhi agreed to mediate between the Assam and Arunachal Pradesh governments but felt that the projects were still a long way from implementation. Environmental impact studies had yet not been prepared. The Bangladesh government has also been viewing them with concern, points out Verghese[111a]. It came to mistakenly believe that the Government of India plans to use the stored water to irrigate 3.5 mha of cultivated land in Assam and Arunachal Pradesh. This could reduce dry season flows in the Brahmaputra at Bahadurabad in Bangladesh by almost a third, which are already below the

SUBMERGED BUREAUCRACY : Only the roof of a government office building in Silchar is visible in the 1989 floods. (CWC)

present and planned, dry season uses of the river's water in the country. But the Indian government has proposed a Brahmaputra-Ganga link canal through Bangladesh which could carry away the waters stored in these dams. The canal has been strongly opposed by Bangladesh.

Soon after the 1988 floods in Silchar, the demand for dams on the Barak also resurfaced. The Central Water Commission believes that a dam on the Barak, at Tipaimukh, at the junction of Assam, Mizoram and Manipur, as proposed in 1954, can go a long way in controlling the floods in the Barak valley[119]. The Brahmaputra Board has suggested a two stage Rs 185 crore scheme which includes construction of the 153 m high Tipaimukh dam[120].

The Mizoram government and the National Hydroelectric Power Corporation are separately investigating the feasibility of a dam at Bhairabi on the Cachar-Mizoram border across the Dhaleshwari and another on the Kolodyne (Kaladan), which flows into Burma. The Dhaleshwari dam will generate 160 mw of power and its lake will spread 80-100 km to Sairang, barely 25 km by road from Aizawl, providing the state with a long waterway. If another dam at Sairang was built as tentatively proposed the state will get a navigable waterway that extends 100 km further south to Lungleh. More than the power the state government is keen to get the dams because of the communications opportunities they provide[111a]. The ministry of environment has objected to these dams because of the pristine riverine forests they will destroy.

Living with floods

While technological interventions to enslave forces of nature continue to attract government agencies, the idea of developing a strategy based on a concept of 'living with floods' is increasingly attracting public and scientific attention. The basic aim of this strategy is to reduce societal susceptibility to flood damage and to reduce those anthropogenic causes that aggravate floods.

For instance, the government of Assam has come up with a scheme to build raised platforms about the size of a football ground for groups of four or five villages in flood prone areas, especially in villages situated near embankments, to provide alternative shelter during the flood period.

ENLIGHTENING DELUGE : The Agricultural University in Nagaon is covered by floodwater, making commuting possible only on makeshift rafts. (Directorate of Information and Public relations, Assam)

These platforms can be raised above a level which has a probability of being flooded only once in hundred years so that even in dire emergency, people can assemble there for protection of life and property.

As these spots will be clearly identified, they will also help the authorities to undertake speedy rescue and relief operations[93]. In 1989, worried by its experience with floods over the last three consecutive years, the Assam government actually constructed numerous 400-500 sqm platforms. The villagers have, however, not been impressed by this idea, according to newspaper reports. The earth used is sandy and they feel that the river would wash them away. But the government feels that if these platforms are successful, more can be built in flood affected areas.

Yet another element of the strategy would be to improve flood forecasting and warning systems and improve disaster preparedness. Rescue of flood victims is often done by boats and helicopters borrowed from armed forces. A well equipped rescue squad could be stationed in all district headquarters with sufficient medicines and foodstuffs. These materials could be stored at specific places in each district which are well known to people.

However, the most important element of such a strategy would be to modify the cropping system in such a way that farmers can cope with floods. Traditionally, low lying areas used to be planted with deep water rice. Even today farmers in various parts of Assam grow this variety, though it is low yielding. They grow it with other varieties to ensure that if the land gets flooded, at least this variety would give them some return. This mixed cropping acts as a sort of insurance policy. Unfortunately, these varieties cannot be grown in all low lying areas because they are adapted only to specific

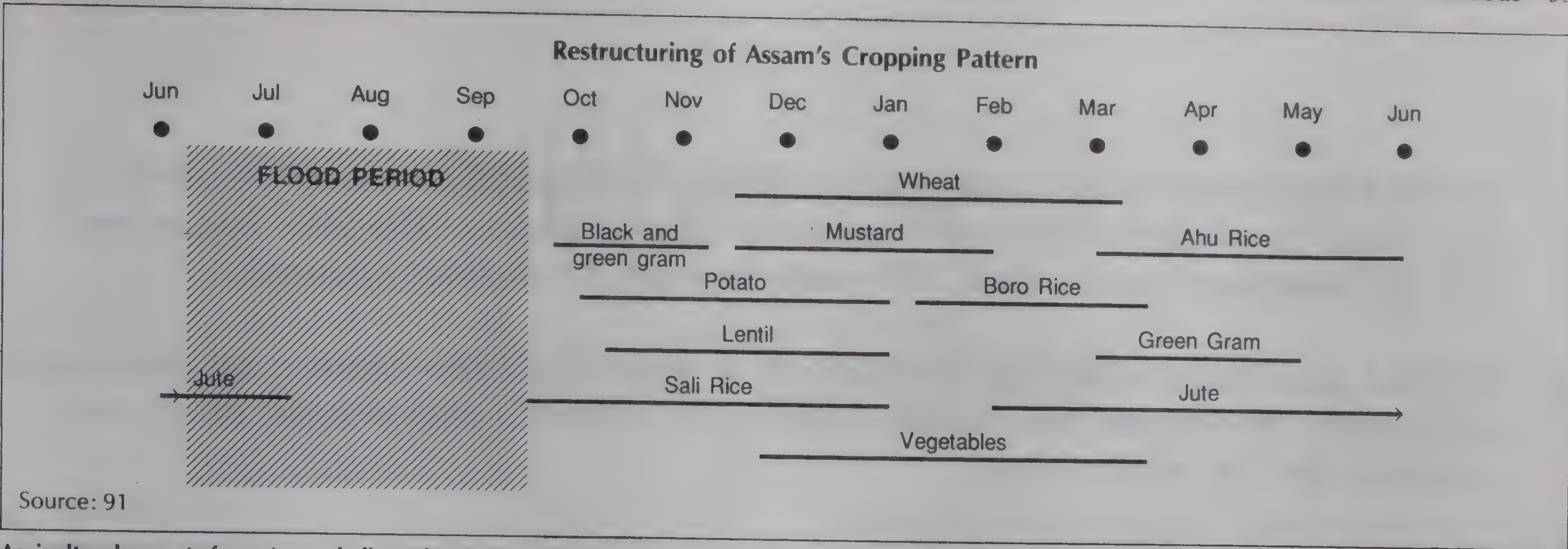
PRONOUNCED BLAME : Jhum cultivation devastates vast areas south of the Brahmaputra and has been blamed for increased flooding in the plains. But it is the northern rivers from the Himalayan slopes which bring more silt and floods. (A M Gokhale)

soil and water conditions. But such traditional practices in agriculture can help experts to plan for the appropriate agricultural development of the area.

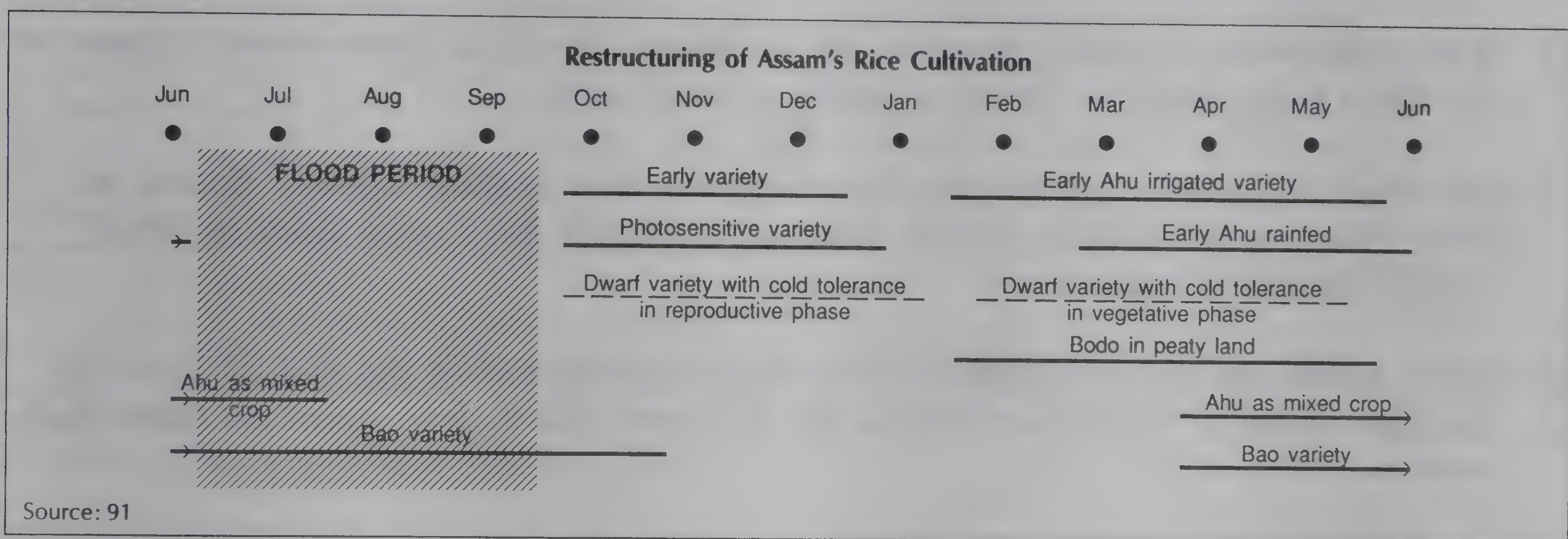
D N Borthakur, former vice chancellor of the Assam Agricultural university, calls for restructuring the cropping pattern to cope with floods. Except for chronically affected areas, all areas can be brought under appropriate land use. The high flood season coincides with main crop of Assam — the sali paddy — from June to November[92]. Usually 75 per cent of the flood damage is to crops[91]. The sali crop occupies more than 75 per cent of the total cropped area. While early floods in the first week of June destroy the standing ahu paddy and jute crops, floods occurring in late August or early September leave practically no time for replanting of rice seedlings and, hence, lead to a total crop loss. But if arrangements were made to supply seedlings quickly, the transplantation of sali crops can be staggered up to mid-September[92]. Contingency planning to make mid-flood season corrections can go a long way to help farmers. Farmers usually face a shortage of seeds and seedlings to start fresh planting after the flood water recedes. The government should be able to supply the appropriate seeds and seedlings immediately after the flood is over [92].

Goswami also argues that "in view of the extensive damages to the sali paddy by recurrent waves of floods, there is an imperative need to shift the emphasis from kharif to *rabi* crops and to practice multiple cropping." Borthakur believes that the restructuring of the cropping pattern is possible. Wheat, mustard, potato, lentil, summer *mung*,

FUTILE EFFORT : Some 253 villages and 8,091 hectares of land in Assam are annually affected by erosion brought about by the Brahmaputra. The picture shows bamboo embankments built to break the force of the river's current. (Assam Flood Control Dept.)



Agricultural experts from Assam believe that it is possible to restructure the cropping pattern in the state to avoid the flood prone months. The season for growing wheat, mustard, potato, lentil, summer mung, boro rice and several vegetables is the flood free period. The major problem lies with rice as Kharif (from July to November–December) is the main growing season for rice.



It is possible to restructure the cultivation of rice, the major crop in the state, in the flood free months, provided suitable varieties (shown by dotted lines) and appropriate facilities are provided.

boro rice and several vegetables are grown in the cold, flood free period. The planting dates of black and green gram can be adjusted during autumn. The kharif rice, which poses the major problem, can also be grown in the flood free period provided suitable varieties for preflood and postflood seasons are selected and suitable irrigation, extension, storage and marketing infrastructure can be developed[91]. As Goswami puts it, agriculture and floods should be seen as the "inseparable two sides of the same coin." Proper management of the colossal flood waters combined with judicious adjustments in cropping patterns can make Assamese agriculture and economy flourish.

Equally important would be to preserve the natural drainage systems and water retention systems in the flood prone areas by developing a strict human settlement policy for the region. The 1986 expert committee, for instance, stressed that newly formed *chars* (islands in the river) should be left to nature as far as possible. Such areas are prone to floods every year and no genuine protection can be given to people living there. The committee even called for resettlement of people living in flood prone areas because land use patterns in riverine areas greatly influence the behaviour of the river.

Appropriate solutions will also have to be found for improving agriculture and survival in the hill ranges surrounding the Brahmaputra and Barak valleys to improve land use in the upland region. Strategies proposed by experts to wean the tribals in the uplands away from shifting cultivation have largely failed because of their economic, cultural and ecological inappropriateness. Deforestation for commercial reasons also needs to be stopped though it continues in a big way.

All this is much easier said than done. As one writer puts it, "Utilisation of the flood plains cannot be stopped even though damages are high since economic efficiency of food production is greater in flood prone areas." Brahmaputra brings not just water but also deposits of fertile silt. Devising a strategy will, therefore, demand immense ingenuity and high skills in agricultural science, hydrology, strict discipline to observe accepted settlement policies and, of course, concern and care on the part of the government. Several experts believe there is no option. The proposed engineering solutions only seem to be worsening the problem and are so expensive that they seem good only for politicians to hold out as dreams. The idea of a controlled Brahmaputra is only a chimera.

- *North Bihar rivers while coming down from the Himalayan mountains bring enormous quantities of silt and constantly change course. The Kosi has moved 120 km westward in the past 250 years through 12 distinct channels.*

- *District gazetteers written by the British at the turn of the century say that local cultivators "welcomed the floods," which left behind a rich deposit of silt, invaluable for the winter crop.*

- *The idea of controlling floods through dams and embankments, in sharp contradiction to the idea of living with floods, came with independence.*

- *With embankments failing to solve the problem, the Bihar government is keen to see dams being built in Nepal, a highly seismic area.*

- *No effort has been made to preserve wetlands as a cushion against floods. In some cases, even notified natural drainage channels have been used to settle landless people to get votes.*

- *Some 3,400 km of embankments have been constructed in the last 35 years at the cost of Rs 375 crore but almost Rs 475 crore have been spent on their maintenance.*

- *The flood prone area in Bihar has shot up from 2.5 mha to 6.4 mha between 1974 and 1988. In 1987 floods engulfed 33 districts out of the 39 districts causing 125 breaches in embankments. Consequently 30 million people were displaced and 1,100 died.*

- *Embankments instill a false sense of security and people continue to occupy the flood plains till a breach occurs, when a tidal wave of water hits them.*

- *Drainage congestion has become a serious problem with the runoff from the fields accumulating where two embankments meet. Bridges, roads and railway lines built against natural drainage compound the problem. Life has become hell for the villages situated between embankments.*

- *A combine of engineers, politicians and contractors, which profits from such measures, is hostile to the idea of non-engineering responses to floods.*

Nightmare in North Bihar

Nothing better illustrates the dismal situation on the flood control front in Bihar than the floods of 1987. Agreed upon as the worst in the century, they engulfed 33 of the state's 39 districts causing losses worth Rs 1,200 crore. The flood incidence was still worse in north Bihar where all districts, barring Siwan, were significantly ravaged. The highest ever known flood levels were exceeded at 10 gauge sites on the north Bihar rivers (see table 43)[125]. In fact the much earlier devastating flood of 1954 in the north Bihar plains, had provoked India's planners to adopt a nationwide programme for flood control. Nevertheless north Bihar continues to occupy an eminent position on the flood map of India.

In the last 35 years, about 3,400 km of embankments have been constructed along the major rivers at an estimated cost of Rs 375 crore and almost Rs 475 crore have been spent on their maintenance[124]. Still, the balance sheet has an alarming story to tell. The flood prone area in Bihar shot up from 2.5 mha to 6.4 mha between 1954 to 1988. Recurrence of embankment failures have assumed unmanageable proportions. Flood damage costs have shot up astronomically.

In 1987, the embankments suffered as many as 125 breaches[125]. Out of 3.4 mha of net cultivated area in north Bihar, 1.7 mha were affected by floods. The damage was complete in 1.1 mha [126]. Road and rail transport was thrown into complete disarray following numerous breaches. Nearly 30 million people were rendered homeless and, 1,100 people lost their lives.

Leading Congress-I leader, Jagannath Mishra, described the situation to the then Prime Minister, Rajiv Gandhi, in the following words "Six feet of water is flowing in Darbhanga, Madhubani, Sitamarhi, Katihar and Jhanjharpur towns with people living on roof tops. A hundred villages have been washed away in Jhanjharpur, Katihar and other districts. People in a thousand villages are marooned. The vast area from east Champaran to Purnea gives the look of an ocean dotted by submerged villages. Lakhs of people have been taking shelter on railway lines, national highways and embankments. In Darbhanga, no place is to be found even to air drop food packets."[127] Even worse, the stagnation of flood waters, technically known as drainage congestion, became so acute that two months after the first spate of floods people were living on embankments. The worst affected were the ones who could afford it the least. By the state government's admission, 85 per cent of the affected families belonged to the category of marginal and small farmers[126].

The state government responded in characteristic fashion, laying the blame in part on the rain god and, in the main, on Nepal. Chief minister Bindeshwari Dubey stated: "We are not able to give sufficiently early warning to the areas where floods occur because Nepal does not allow us to install warning devices"[128]. While conceding the limitations of embankments as a flood control mechanism, the expert committees set up in the wake of 1987 floods, nonetheless, recommended a further elevation of the existing embankments. The government argued that until the time big dams come up in the Nepal Himalaya, it will be forced to stick to embankment construction as a measure of flood control. Engineers and environmentalists alike emphasised that extensive deforestation in Nepal had aggravated the problem of floods in north Bihar plains.

The opposition, while extremely critical of the government, did not present any different perspective on flood control. Its grouse was not against the existing measures and concept of flood control but against their inadequate

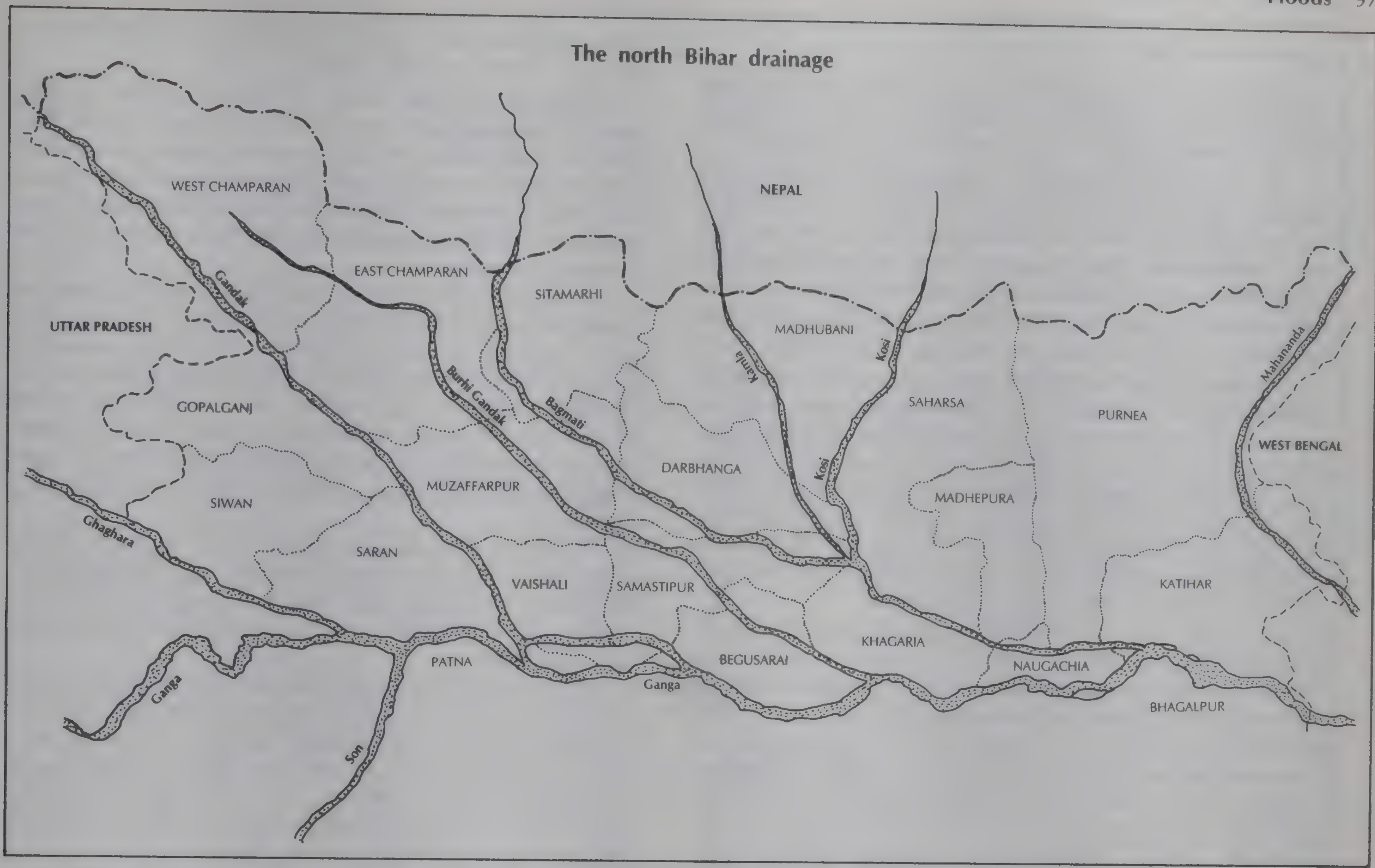
Table 43

Record of highest flood levels in north Bihar

Name of river	Gauge site	Highest flood level until 1987 (m)(year)	Highest flood level in 1987 (m)(date)
Burhi Gandak	Sikandarpur	53.93 (1975)	54.29 (15-8-87)
	Samastipur	49.12 (1986)	49.38 (16-8-87)
	Rosera	45.98 (1974)	46.35 (16-8-87)
Baghmati	Benibad	49.56 (1979)	49.66 (15-8-87)
	Hayaghat	48.06 (1975)	48.96 (15-8-87)
Adhwara group	Ekmighat	48.57 (1975)	49.27 (15-8-87)
Kamla Balan	Jhanjharpur	51.83 (1975)	52.73 (12-8-87) 51.97 (11-8-87) (Date of breach)
Kosi	Basua	48.44 (1979)	48.65 (12-8-87)
	Baltara	35.37 (1974)	36.40 (16-8-87)
Mahananda	Jhawa	33.40 (1977)	33.51 (14-8-87)

Source : 126.

FLOOD VICTIM: A hamlet in Madhubani district comes in the grip of floods. Floods in 1987 affected 33 of Bihar's 39 districts causing losses worth Rs 1,200 crore. (Krishna Murari Kishan)



North Bihar is drained by an extensive network of rivers, practically all of them have their catchment in the Nepal Himalaya.

pursuance by the state government. In sum, therefore, all were agreed that afforestation and construction of dams in Nepal and embankments in Bihar would alone help to solve the problem. But, indeed, in an area so naturally prone to floods, will the solutions be as simple ?

ECOLOGICAL SETTING

North Bihar plains are drained by an extensive network of rivers, most of which flow into the Ganga. Practically all of these have a part of their catchment in the Nepal Himalaya. Gandak and Kosi have a part in Tibet as well (see table 44). The catchment of all these rivers receive more than 80 per cent of their annual precipitation from June to September. Consequently, the bulk of their annual runoff and high sediment load (as high as 80 per cent) is from June to October[129,5]. All these rivers carry an excessive sediment load. With the exception of Burhi Gandak, they have a steep course in their upper Himalayan reaches but face very abrupt flattening of the gradient on entering the north Bihar plains. This considerably retards their sediment carrying capacity and what follows is an excessive siltation of their beds in the lower reaches. This lends the rivers an aggrading character and consequently a reduced channel capacity. Practically all the rivers except Burhi Gandak have an aggrading characteristic.

The aggrading character of these rivers, with their built up river beds, obstructs the natural drainage and the phenomenon of braiding is a characteristic of most of them. Shift in courses is a recurring feature. Most rivers have a network of abandoned courses which serve as spill channels or drainage channels during floods. The Kosi, for example, has moved westwards by 120 km in the past 250 years through more than 12 distinct channels. The river which used to flow near Purnea in the 18th century now flows west of Saharsa[60].

The Kosi

A closer look at Kosi puts in sharper relief the drainage characteristics of this region. The Kosi, one of the largest tributaries of Ganga drains the hilly area east of Kathmandu in Nepal, including the world's two highest peaks of Everest and Kanchenjunga. In Nepal, the river has seven streams, which give it the name Sapt Kosi below Tribeni, where the three main streams, Sun Kosi, Arun and Tamur, join. Further down, the Kosi cuts a deep gorge across the lesser Himalayan range of Mahabharat Lekh and debouches into the plains near Chatra. After flowing for another 58 km, it enters the north Bihar plains near Bhimnagar and after another 260 km, flows into the Ganga near Kursela.

The river has a steep gradient of 47 m/km, in its upper reaches, but after Chatra it rapidly flattens to only 1 m/km[9]. The annual rainfall in the catchment up to the Nepal border varies from 1,500 mm in the foothills to 4,060 mm on the southern slopes of the Himalaya, gradually decreasing to 250 mm in Tibet. The average river discharges rise steadily from 2,000 cumecs in June to 4,500 cumecs in August. The average peak discharge is of 5,600-7,000 cumecs during July and August. The highest recorded discharge was 24,200

GRAND FAILURE

The most grandiose scheme to come up in north Bihar, the Kosi project has proved to be a failure on all counts. The Kosi barrage at Hanumannagar has, in fact, already outlived its utility.

The barrage was designed to distribute the flood waters between the main channel and the various *dhars* in proportion to their capacities; and, store sufficient water to irrigate 0.81 mha. An eastern embankment of 144 km and a western embankment of 123.2 km was built with the distance between embankments ranging from 4.8 km to 16 km. The area, thus protected from floods was estimated to be 0.265 mha.

A Central Water Commission report on Kosi in 1982 stated that after it's completion in 1963, the barrage began inducing siltation. The rise and fall of the river bed was estimated over six stretches. In three reaches, the earlier phenomenon of river bed scouring changed to siltation after the barrage was built and in one stretch, the scouring rate was greatly reduced. Overall, the annual silt deposit over the river bed between the embankments went up from 16 mcum during the period 1955-62 to 84 mcum during 1963-74 (see table)[1].

The report, however, cautions against any hasty generalisations as this analysis is, according to it, only for a short period. Similar reservations are expressed by another expert, N Sanyal, who argues that though, in general, some of the river reaches have shown a tendency of aggradation after the project, there are some reaches where the river has also shown a tendency of lesser silt deposits and lesser aggradation. The impact of the embankments on the Kosi is, therefore, not uniform. Thus, the available scientific studies leave a note of ambiguity. But repeated floods have in any case shown the project to be a failure in terms of flood control.

The project is also aimed to develop surface irrigation through a network of canals. But these canals do not have adequate water during the non-monsoon months whereas they have a surplus during the flood season. Moreover, their capacity has been considerably reduced due to excessive siltation. Thus, instead of benefiting agriculturists, they have compounded the scourge of floods.

Laying out of these canals was characterised by ecological insensitivity and neglect of traditional wisdom. The north Bihar plains are made up of new alluvium with a high moisture retentive capacity and, with the exception of Muzaffarpur and Saran districts, fall in a high rainfall area. Consequently, Nirmal Sengupta, an expert on traditional irrigation practices, states, "In the continuous plain of north Bihar, floods and waterlogging was a more serious problem than the requirements of irrigation"[2].

Because of the high groundwater table, numerous *kaccha* wells, lasting for a year or two, used to be dug in the dry district of Saran as well as in areas near the Ganga river in all the northern districts. Further north, irrigation covered only a small area (see table).

Byrnes, a British civil servant, working in Purnea district said around 1910 "There is no attempt at and little need for systematic irrigation. A temporary well is excavated in every plot that grows tobacco. It costs very little to make as water is usually found at a depth of 3.5 or four m even in winter." L S S O'Malley, another British civil servant, who compiled the first gazetteers for Bihar points out, "Irrigation is little practiced

Impact of Kosi project on the river bed

River stretch	Change in river bed levels		Volume change in river bed		Remarks
	Prebarrage (1955-62) (cm/yr)	Postbarrage (1963-74) (cm/yr)	Prebarrage (1955-62) (mcum/yr)	Postbarrage (1963-74) (mcum/yr)	
Upstream of barrage					
Chatra to Jalpapur	– 1.76	+12.34	– 4.046	+28.304	Scouring has changed to siltation after the barrage
Jalpapur to Bhimnagar	– 16.56	+10.70	– 16.058	+10.436	As above
Downstream of barrage					
Bhimnagar to Dagmara	– 3.56	– 0.83	– 5.082	– 1.181	Scouring has reduced considerably after the barrage
Dagmara to Supaul	– 0.38	+ 1.86	– 2.081	+10.228	Scouring has changed to siltation after the barrage
Supaul to Mahesi	+ 9.56	+ 6.35	+42.90	+20.949	Rate of siltation has reduced after the barrage
Mahesi to Koparia	NA	+12.03	NA	+15.730	Postbarrage siltation has at a high rate of 12.03 cm/yr.
			+15.633	+84.466	

Source : 1

Incidence of irrigation in north Bihar districts in the preindependence period

District	Percentage of cropped area irrigated in 1931 (%)
Purnea	1.53
Darbhanga	5.81
Champaran	7.35
Muzaffarpur	8.59
Saran	15.62

Source : 3

and little needed. The rainfall is ordinarily ample, and it begins early. There are usually storms from March onwards; rain falls in April and May, which is of great service to jute and indigo; and, the monsoon is well established in June."

Traditional irrigation relied on a system of *pains* (or artificial channels) which led off from the river, especially in several subdivisions, of the then Darbhanga district. This system was facilitated by the numerous streams and rivers which intersected the land. O'Malley noted, "All irrigation projects in Madhubani, accordingly, suffer from the defect that they would be little used in ordinary years, while in dry years they would benefit a comparatively small area. Hence, large irrigation works are probably financially impossible, and any extension of irrigation must be looked for, mainly in the direction of increasing the usefulness of the present sources of supply by some cheap and efficient system, such as that which has already proved so successful in Benipatti. Well irrigation is practically useless for winter rice, owing to the small area commanded by each well, and no wells would stand in an area so liable to inundation. But tanks can already irrigate 18,211 ha in the subdivision, and rivers and channels nearly 20,234 ha. It would probably be possible to improve the manner in which these two sources of irrigation are used, at a cost which would be insignificant in comparison with the advantage to be gained, and this would go far to render a large part of the area secure against a failure of the monsoon"[3].

After independence, the Kosi project was conceived as a flood protection measure. But later, largely because of the influence of the World Bank, irrigation was added to its purpose in spite of local objections. However, time has proved that neither the Kosi project nor the Gandak project (which followed the Kosi project) have been welcomed for irrigation. As Nirmal Sengupta observes, "In a region where there is little need of irrigation, irrigation projects can never find good reception. Thus, in all the canal command areas in north Bihar the cultivators have shown great reluctance to construct field channels to receive water. The task, originally entrusted to the beneficiaries, has now been taken up by the irrigation authority." This has led to widespread waterlogging. Recent estimates place the damage from waterlogging and salinity by the Gandak project at Rs 180.4 crore. Nirmal Sengupta claims that, everywhere in north Bihar, waterlogging has become a widespread contribution of all irrigation projects.

While the Kosi and the Gandak projects stand out as epitomes of what a technology, devoid of ecological perspective, can lead to, the state government has recently gone ahead to clear the Baghmati project conceived along similar lines.

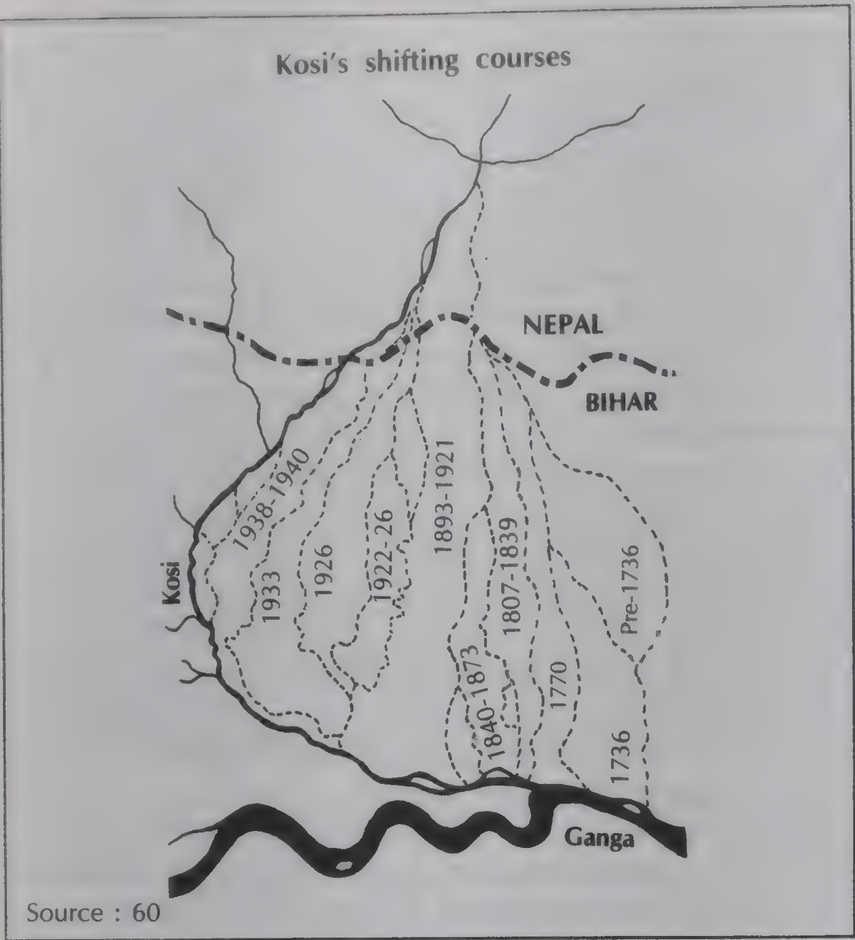
cumecs on August 24, 1954[130].

Due to extensive soil erosion and landslides in its upper catchment caused by factors both natural and human, the silt yield of Kosi is about 19 cum/ha/yr, one of the highest in the world[9]. The Arun, with its origins in Tibet, brings the greatest amount of coarse silt in proportion to its total sediment load. Since the Kosi in its upper reaches not only has a steep gradient but also flows through a narrow and deep valley with steep sides, it carries its sediment load straight into the plains. Beyond Chatra, on account of a progressive flattening of the bed gradient, the river first deposits boulders, pebbles and shingles for over a distance of 32 km. Following a further drop in the gradient at Belka, the river starts to throw its sediment load down to Hanumannagar. This deposition of its sediment bed load explains the braided patterns of the river in this reach. Below Hanumannagar there is a further flattening till Bhaptiahi. Here, a further drop in bed slope leads to more deposition of sediments and a high rate of aggradation. The river branches off into a number of interlacing channels, which shift their course from time to time.

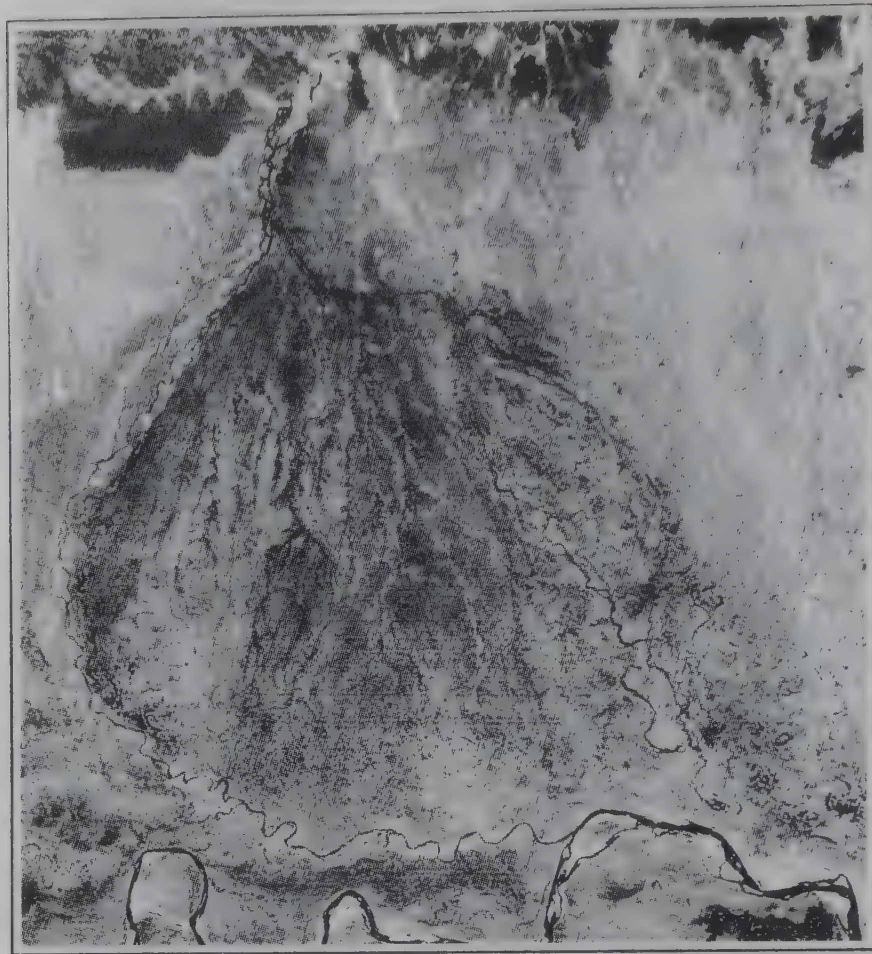
In sum, the Kosi spills its banks in the monsoon due to excessive rain; deposition of coarse silt on fertile lands; and, shifts in its courses leading to the formation of numerous *dhars* (channels). The basic factors, which cause the lateral movement of the river, are an excessive silt load; erosion prone low banks, which are ineffective in confining flood waters or maintaining a definite channel; a large discharge; and, a lateral slope of the plains, which assists the movement of the river by inducing pendulum action starting at the bends.

Kosi typifies the malaise that characterises the north Bihar rivers in its most extreme form. The problem of shifting courses is also characteristic of Kamla and Bagmati. During this century Kamla has changed its course thrice. It used to flow west of the old town of Jayanagar on the Indo-Nepalese border and shared the same bed with river Dhons Bagmati for about 10 km on the western border of Madhubani district. During the second quarter of the century, it changed course to the east of Jayanagar, mercifully sparing a part of this town, but cutting off Madhubani town from three sides. In the beginning of the third quarter of this century, it made another eastward jump and occupied a bed deserted by Kosi about 300 years ago and almost devoured river Balan, becoming known as Kamla-Balan[131]. Bagmati made its last big shift just a decade ago, when an already constructed 32 km long embankment on both its sides, had to be given up. Lal Bakaya, Lakhendayi, Khiroi, Burhand and Dhons Bagmati rivers merge into Bagmati at several places turning into one river to the south of Darbhanga town. This river group is known as the Adhwara group of rivers[131].

Fortunately, Gandak and Mahananda have a slightly different behavior pattern. Gandak's long course through the Pokhara valley and beyond in Nepal is on a low slope and its confluence with Panch Gandaki is at a low height. Therefore, it lacks this perpetual course shifting characteristic. Mahananda is not much different but erosion, breaches and overflowing by this river do frequently cause huge damage.



Shift in courses is a regular feature of north Bihar rivers. The Kosi for example has moved westwards by 120 km in the past 250 years through more than 12 distinct channels. The river which used to flow near Purnea in the 18th Century, now flows east of Saharsa.



A satellite picture of the various migrations undergone by the Kosi. (NRSA).

ROAMING RIVER: The Kosi about to change its bed. Eventually the circular meander will get cut off from the main stream leaving behind an oxbow lake while the river finds itself a new route.(Krishna Murari Kishan)

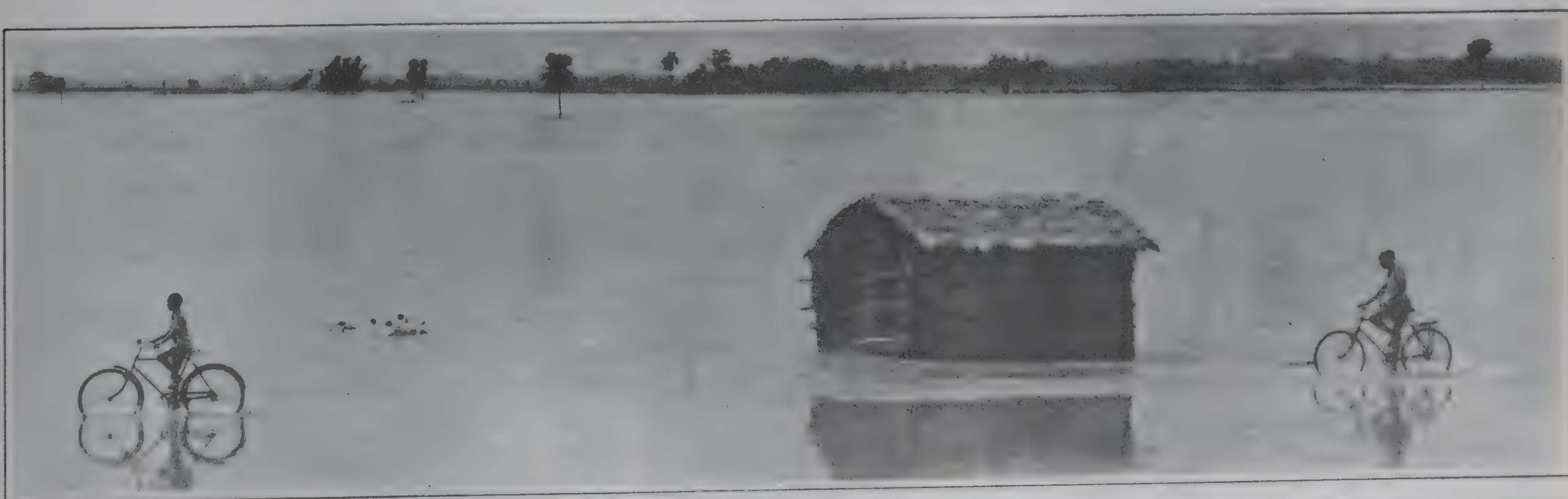
Table 44

Catchment characteristics of north Bihar rivers

Name of the catchment	Total basin area				Length	Annual Rainfall	Per cent during monsoon period	Districts in India over which the catchment is spread
	India (mha)	Nepal (mha)	Tibet (mha)	Bangladesh (mha)	(km)	(mm)	(%)	
Ghaghara (excluding Rapti)	4.35	5.57	0.23	–	780	970-1360	86-89	Deoria, Ballia, Gorakhpur, Azamgarh, Faizabad, Basti, Gonda, Barabanki, Bahraich, Sitapur, Lakhimpur, Pilibhit, Pithoragarh and Almora (all Uttar Pradesh), and Saran (Bihar)
Gandak	0.69	2.70	0.47	–	420	1120-1390	85-86	Saran, Muzzaffarpur and Champaran (all Bihar) and Deoria (Uttar Pradesh)
Burhi Gandak	1.13	0.24	–	–	320	1180-1390	84-86	Munger, Darbhanga, Muzzafarpur and Champaran (Bihar)
Baghmati-Adhwara	0.73	0.62	–	–	240	1180-1390	83-96	Munger, Darbhanga, Muzzafarpur and Champaran (Bihar)
Kamla Balan	0.66	0.48	–	–	150	1210-1380	82-84	Munger, Darbhanga and Saharsa (Bihar)
Kosi	0.92	3.07	2.94	–	390	1380-1590	81-82	Purnea, Saharsa and Munger (Bihar)
Mahananda	1.62	0.40	–	0.30	240	1540-3900	78-82	West Dinajpur, Darjeeling, Jalpaiguri and Malda (all West Bengal) and Purnea (Bihar)

Source: 129

All this notwithstanding, there is a major difference between Kosi and other river systems of north Bihar, mainly in the quality and quantity of sediment load. Not only is the sediment load in Kosi five times as high as that of any other river but the percentage of coarse and medium silt is as high as 45 per cent of the total[130]. The excessive coarse sediment carried down by the Kosi is ascribed to the fact that the Himalayan valleys are narrower in its catchment area, and there are no wider basins in the hill region for the river to deposit its coarse sediment load. On account of the steep



DISASTER AREA: The river submerges a vast area converting it into a sheet of water extending across Madhubani district. In 1987 six feet of water was flowing in Madhubani. The vast area from east Champaran to Purnea gave the look of an ocean dotted by submerged villages. (Krishna Murari Kishan)

and high mountain sides, frequent landslides occur adding to the coarse sediment load. Boulders, pebbles and shingles which come down into the river, are rolled down into the plains. Geologically, a wide area on either side of the Sapt Kosi between Tribeni and Chatra is a thrust zone, wherein, due to the folding and faulting accompanying the mountain building activity, the older rock strata has slid over the younger formations.

This reversal of the older rocks riding over the younger ones has brought to bear excessive stresses which have resulted in considerable shattering of the rocks over the area and on its margins. In addition, frequent seismic disturbances, especially the intense earthquake of 1934, have further accentuated the loosening up and disintegration of the already shattered rocks in this region.

This zone extends over the area through which the Sun Kosi and the Tamur flow and constitutes a major factor for the excessive sediment and bed load of the river. It is this qualitative and quantitative character of its sediment loads that had led to the river's extreme vagrancy. An excessive discharge during monsoons coupled with an excessive sediment load not only lead to the inundation of an extensive area in north Bihar but also to the deposition of volumes of sand over croplands, thus, destroying their productive power, choking of wells and depriving villagers of their homesteads. However, it has also actively built up land and, in fact, the western half of Purnea district owes its physical characteristic to the river.

HISTORICAL BACKGROUND

Floods in the north Bihar plains date back to antiquity. The settlement of this area began as early as the 7th century B C with agriculture getting to be the dominant productive basis of society. It saw not only the emergence of the first kingdoms like those of Magadha and Vrijjis but also the foundation of the first empire recorded in Indian history, namely, the Mauryan Empire. The rich agricultural resources made no mean contribution to this process of state formation. Extensively irrigated by a network of perenniai rivers, the fertile soil base of new alluvium deposits, falling in a favourable rainfall zone, could effectively produce two to three crops a year even with low technological inputs. This engendered a social surplus that could sustain civilisation growth down the centuries. The natural fertility of the soil was replenished by the silt deposits of inundating rivers.

However, this inundation, which could once be rated as nature's bounty, gradually transformed itself into a curse. This feature, initiated by colonial intervention, became particularly pronounced from the onset of the 20th century. An expanding population within the constraints of a colonial economy led to growing pressure on land. During the British *Raj* Bihar experienced the worst form of exploitative imperialism. The Permanent Settlement stripped peasants of customary rights, deserting them to the mercy of landlords. Their bargaining position was further corroded by the simultaneous ruination of traditional arts and crafts (often referred to as deindustrialisation) which pushed people into agriculture and brought to bear considerable pressure on land. Cumulatively, these two factors led to the occupation and cultivation of the marginal and submarginal lands. The appropriation of control over the more fertile tracts for purposes of commodity production by the colonial rulers further pushed the poor peasants towards an occupation of the flood plains. Consequently, floods started wrecking greater havoc than they had done before, or at least seemed to.

This changed perception about floods is amply reflected in the district gazetteers which maintain a meticulous record of the floods that ravaged the area from the turn of the 19th century onwards. However, the attitude was still not one of viewing them as an unmitigated evil, but a necessary one. For instance, the Muzaffarpur district gazetteer states, "This area through which Bagmati flows is the most fertile part of the country and practically every acre of land is cultivated. The fertility of this area is renewed by the visitation of floods depositing alluvial silt brought from the hills. Flood is almost a necessary evil and this part of the country cannot do without flood." There are numerous references to how the loss of kharif was more than compensated for by a bumper rabi harvest, thanks to the rich silt deposit left by the receding waters. The Darbhanga district gazetteer explicitly states, "Owing to this combination of circumstances, the district has always been subject to severe and widespread inundations, which cause a good deal of temporary suffering. But, as a rule, the distress they cause soon passes away, the dwellings which are destroyed are quickly replaced, as the cost of erecting such mud walled huts is small; and, the cultivators are compensated, in large measure, for the losses they sustain by the fertilising silt left by the receding waters, which increases the productivity of the soil and ensures rich crops."

A substantial part of the kharif produce was lost in years of exceptional flooding. In years of moderate floods, not only would the kharif crop survive but it would also be followed by a bumper rabi harvest. The flood waters in most cases would recede in eight to 10 days — a period of submergence the kharif paddy could often safely withstand. At the popular level, living with floods was not only considered necessary but also desirable. The Darbhanga district gazetteer, speaking of the 1902 floods, says, "Inspite of the losses they sustained, the cultivators in the north welcomed the floods. In the preceding year the rainfall had been deficient, and the winter rice crop had nearly failed in some parts. Here the floods were of comparatively short duration, but they sufficed to replenish the empty tanks and wells, and left a thick deposit of silt, which was invaluable for the rabi crop and ensured a full winter rice harvest, where seedlings were available."

The idea that the government should tackle the problem through extensive embanking of rivers dates back to 1896-97, when in a conference in Calcutta, presided over by the secretary to the Government of India in the public works department, this idea was mooted with regard to Kosi. However, as stated in the district gazetteer of Saharsa, "the proposal was considered to be of doubtful efficacy and it was concluded that no steps were feasible for controlling

FLOOD REFUGEES: While embankments fail to guarantee protection against floods they nevertheless offer refuge to flood victims deprived of their homes by flood waters. (Krishna Murari Kishan)

the course of this big river with its numerous channels and wide and elevated beds, beyond protecting, by short lengths of embankments, isolated tracts exposed to its floods." Again, in 1937, at a conference organised by the then provincial ministry of Bihar, the chief engineer of Bihar favored "an all out policy of removing all embankments, on the plea that the embankments did more harm than good, that they merely transferred trouble from one area to another and that they gave rise to a false sense of security"[132].

Apart from these two instances of technical opinion against embankments, there are other instances cited by the district gazetteers, which amply reflect the unfavourable disposition towards embankments. The Darbhanga district gazetteer states, "private bandhs or embankments (have) made matters worse for the villages downstream, and in the end when the floods have asserted themselves, and spread over the country, they hedge them in and delay their subsidence." The gazetteer also states in the context of the 1902 floods that "though the people complained of the embankments and of the passage of the flood, no complaints were made about the occurrence of the floods itself."

All these factors notwithstanding, a Western bred technocratic vision had already come to visualise human intervention into the river's natural regime as a matter of right. On two occasions the issue of embanking these rivers arose but each time the idea was shelved as it was felt that its disadvantages would far outweigh its advantages. Nonetheless, the will to exercise control over the river's regime had come to be there. The wait was only for better ways of taming it.

In the wake of independence in 1947, caught up as Indian leaders were in the belief of what a technologically superior nation could inflict on a technologically inferior one, they hazarded themselves into a wholehearted imitation of the Western model of development, thus, severing their links with the native intellectual tradition which had as its cornerstone the principle of harmony in contradiction to the Western inheritance of the principle of conquest. This transformed consciousness so permeated the educated Indian mind that the formulation of the National Flood Control Policy in 1954 could not escape this hydra-headed trap. It was emphatically stated that floods could be controlled through a series of flood protection works like dams, embankments and river training works.

FLOOD CONTROL AFTER INDEPENDENCE

Following the formulation of the National Flood Control Policy in 1954, the dominant measure of flood control adhered to in north Bihar has been the construction of embankments. Though *Zamindari* embankments had covered small tracts of the north Bihar landscape prior to 1954, construction of embankments, as a major state enterprise, was mooted for the first time in the Kosi Project. Since then, all major north Bihar rivers have been systematically embanked and the effort goes on to this day. As stated in a Bihar government report of December 1987, a total of 3,438 km of embankments had been constructed in Bihar up to the end of 1986-87 (see table 45). Of these, 2,951 km fall in north Bihar. Whereas Kosi and Piprasi-Pipraghat embankments on the Gandak account for 270 km and 35 km, respectively, the rest have been constructed along such rivers as Ganga, Mahananda, Burhi Gandak, Ghaghara, Kamla Balan, Bhutahi Balan and Bagmati. The report explicitly states that "until now flood protection in Bihar is being given by constructing marginal embankments" [133].

Table 45

Embankments in Bihar

Period	Embankments constructed (km)	Area protected (mha)
End of the Sixth plan	3396	2.883
Seventh plan (1985-86 & 86-87)	36	0.030
Total up to 1986-87	3432[1]	2.913
1987-88 (anticipated)	20	0.010
1988-89 (proposed)	30	0.250

Note : [1]Of which 2951 km was constructed in north Bihar

Source : 133

Negative impacts

The construction of embankments has had a disastrous impact. Though the absence of data for a dependable evaluation of the performance of embankments is a severe constraint in making an objective assessment of their impact, there are other reasonable indicators which can help to judge them.

That the river beds, in case of most of the north Bihar rivers, have gone up following the construction of embankments, is strongly confirmed by the local residents of the area as well as by local environmentalists. The relief and rehabilitation commissioner in his report on the floods of 1987 has explicitly admitted that siltation has had a negative impact on the flood discharge capacity of river Kosi: "the highest flood level (HFL) at Baltara (in 1987) exceeded the high flood level ever known, by one metre. This happened when the maximum flood discharge was slightly above 14,100 cumecs whereas the flood discharge of the Kosi was as high as 24,200 cumecs in 1954 and 1968. This shows that heavy siltation has occurred"[126].

This admission is a direct pointer to the way embankments have adversely affected the river's morphology. The figures on record flood levels and the incidence of breaches adding up to 90 in 1987 — 48 major (exceeding 91.5 m) and 42 minor (up to 91.5 m) — on the different rivers are further pointers to the problem created by embankments as a flood protection measure[126].

The natural fertilisation of the flood plains has traditionally far outweighed the negative consequences of the floods in the people's consciousness. While the state government has not been forthcoming on how embankments have impacted on agricultural lands, news reports have quoted villagers on how embankments have robbed them of the

Table 46

Frequency of flood years in north Bihar districts (1968-76)

Bihar districts	Frequency of floods in the nine years between 1968-76
Saharsa	8
Darbhanga	8
Muzaffarpur	8
Munger	8
Purnea	8
Chapra (Saran)	7
West Champaran	7
Katihar	4
Madhubani	4
Sitamarhi	4
Vaishali	4
Samastipur	4
Begusarai	4
Gopalganj	3
East Champaran	3
Siwan	2

Source : 5.

natural soil fertility replenishment. Farzand Ahmed of *India Today* reports that "the Bagmati river project in the Sitamarhi district in Bihar (has) reduced the once fertile district area into a dust bowl. What the vast army of engineers and contractors put together for the project has done is to construct (160 km long) sand and earth embankments on both sides of the river, starting from the Indo-Nepal border. This has prevented the Bagmati from spilling over its banks."

According to Ahmed, however, the farmers of the area welcomed the floods which time and again increased the land's fertility. As a local resident put it to him, "Until the embankment came up, the district was considered a gold mine with bumper crops almost every postflood period. But now the district is a dry patch as the Bagmati water locally called *amrit* (nectar) has been caged" [134].

The district gazetteer of Muzaffarpur also pointed out in the wake of 1953 floods, "As a matter of fact, observations stretched over a number of years have shown that the area which is deprived of the Bagmati spill begins losing the fertility of its soil. The area which remains in constant touch of the Bagmati spill or new area which is visited by flood, retains fertility of the soil."

The Hindi daily *Hindustan* has also highlighted in its Patna edition (October 20, 1987) the devastation caused by the embanking of Kamla Balan. The report quotes 80 year old Prem Shah, " Prior to embankment construction, annual flooding would leave behind rich silt deposits ideal for *dalhan* (pulses) and *telhan* (oilseeds) cultivation without using manure and fertilisers. Following the construction of embankments, this potential for annual replenishment of silt was lost. Consequently, agriculture has become fertiliser and irrigation dependent." The *Hindustan* report goes on to add that while prior to construction of embankments there is no record of loss of life, the 1987 floods had left thousands dead in their wake. Elders of several villages also argued that in Benipatti subdivision where no embankment has been constructed, there has been little damage to life and property and productivity, too, has not been adversely affected.

All these factors notwithstanding, certain experts argue that the losses suffered due to silt loss have been more than compensated by the cropped area protected from floods. Simply speaking, it is suggested that crops, which would

Table 47

Annual flood damages in Bihar (1953-84)

Year	Area affected (mha)	Population affected (million)	Total damage to crops, houses and public utilities (Rs crore)
1953	0.97	6.77	36.50
1954	2.50	7.67	21.50
1955	1.77	7.11	21.62
1956	1.32	3.12	5.73
1957	0.79	1.73	NA
1958	0.71	2.37	3.21
1959	0.21	1.01	NA
1960	1.32	2.45	0.006
1961	1.27	4.68	13.25
1962	1.11	4.01	10.13
1963	0.27	0.70	0.76
1964	1.12	3.81	13.27
1965	0.43	1.83	1.80
1966	1.53	5.87	39.00
1967	1.25	6.43	19.67
1968	0.73	3.56	10.16
1969	0.97	4.17	36.00
1970	0.93	3.89	15.07
1971	4.26	21.71	217.44
1972	0.22	0.90	1.70
1973	0.73	3.14	20.06
1974	3.14	16.43	381.83
1975	2.31	13.24	265.76
1976	2.99	13.64	205.99
1977	1.15	3.08	12.29
1978	2.37	12.06	178.86
1979	0.81	3.74	20.19
1980	1.92	7.45	57.73
1981	1.26	6.95	79.08
1982	0.93	4.68	113.42
1983	1.47	5.07	26.29
1984	2.64	11.68	139.50
Total	45.4	194.95	1967.84
Maximum	4.26 (1971)	21.71 (1971)	381.84 (1974)
Average	1.42	6.09	65.60

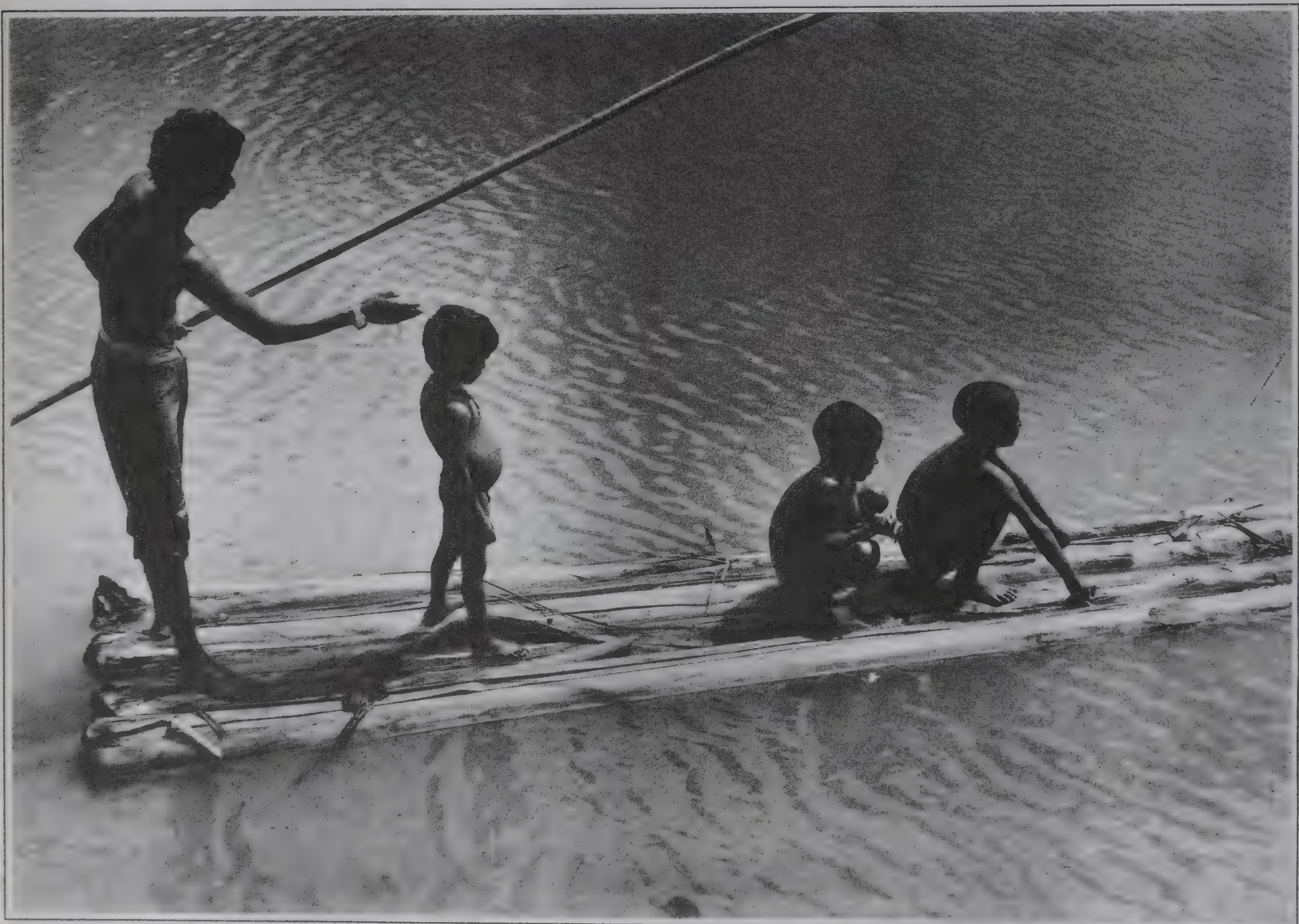
Source : 6

otherwise have been damaged by the floods, stand protected in the wake of embankment construction. This offsets the losses accruing from the loss of silt deposit. In addition flood protection induces farmers to go in for high yielding varieties, thus, raising the productivity of their plots. But detailed studies on the effect of embankments on crop productivity in the region are not available.

Embankments also seem to have increased the high flood levels. The Muzaffarpur district magistrate's report on the floods in 1987 states that while the floods of 1954 had been the worst and the most devastating for the Muzaffarpur district, the 1987 floods surpassed that limit by a very high margin and caused destruction of such a magnitude which was beyond imagination. During the 1987 flood, water was flowing 86 cm above the highest flood level of 1954, and 12 blocks out of 14 blocks faced unprecedented devastation.

While the first flash of flood came on August 2, 1987, affecting two blocks, the situation became grave in the whole district from August 8 onwards. "During this period the water was rising menacingly in all the rivers and was inundating more and more areas which had never faced such a situation in the past," says the report. It explains this unprecedented flooding in terms of very heavy rains and the breaching of numerous important embankments. These breaches, as per the report, "let loose a five to six feet high wall of onrushing water which uprooted trees, houses, buildings, roads, that is, whatever came in its way."

News reports on the flood situation in Khagaria district in October 1987 quoted the villagers attributing the devastation to the construction of embankments on Bagmati (Kareh), Burhi Gandak and Kosi. According to them, flood waters would earlier register a rise of 0.6 to 0.9 m in 12 to 15 hours and then recede. In 1987, they came as a cascading sheet of 2.4-4.3 m washing away entire villages[136]. Journalist Kuldip Nayar's report on north Bihar floods also quoted people claiming that dykes and embankments had brought disaster to them and they would have been better off if the flow of rivers had not been obstructed. In the old days floods did less harm and they had learnt to live with them[128]. Prior to embankments, the rivers would swell gradually giving the people considerable warning time to retreat to safer quarters. The embankments, by engendering a false sense of security, have made the people complacent. They continue to occupy the hazardous flood plains till the breach occurs. This, coupled with the fury with which the flood waters now strike the adjacent countryside, has considerably added to the magnitude of the damage.



SOCIAL DISASTER: The poor and the deprived are often the worst victims of floods. During such moments even rafts made out of banana tree trunks are a help. (Krishna Murari Kishan)

Table 48
Flood damage trends in Bihar

Period	Average annual area affected (mha)	Average annual crop area affected: Actual (mha)	Average annual crop area affected: % of total affected (%)	Average annual population affected (m)	Average annual total damages (Rs crore)	Average annual crop damages: Actual (Rs crore)	Average annual crop damages: % of total damages (%)
1950s (1953-59)	1.18	0.67	57	4.25	12.65	10.38	82.05
1960s (1960-69)	1.00	0.45	45	3.75	14.41	13.37	92.85
1970s (1970-79)	1.89	0.75	40	9.18	131.92	83.15	63.03
1980s (1980-84)	1.64	0.74	45	7.17	83.20	61.55	73.98

Source: 6

Drainage congestion has become a particularly significant problem in north Bihar with the construction of embankments as it falls in a heavy rainfall zone and consequently has a large runoff. During heavy rains, there is runoff from the fields which then accumulates at all those points where embankments of two rivers meet. North Bihar is drained by an extensive network of rivers and because they have been embanked to a great extent, this particular aspect of drainage congestion has assumed a significant dimension. The impact of embankments on drainage congestion is testified to by the local populace. In their opinion, while the flood water would, in most cases, subside in a week's time in the preembanked stage, it persists for a much longer duration in the postembanked phase.

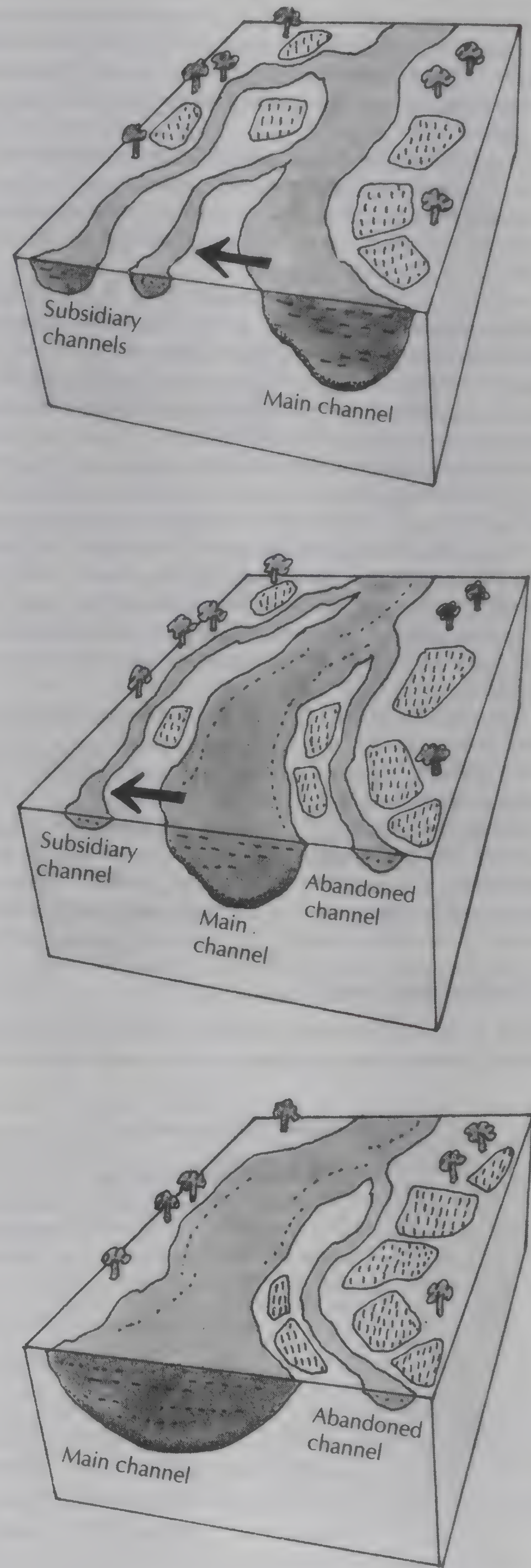
Reports on the August 1987 floods in the Patna edition of the *Hindustan* mention vast tracts submerged under flood waters even until October. For instance, journalist Hemant, in his report of October 7, speaks not only of half a dozen districts with vast tracts still under water but also of 0.35 million people marooned on the embankments of the flood affected districts. On the government side, this issue is generally glossed over.

With river beds rising after embanking, the protected area along the embankment on the river Kosi and Gandak is getting waterlogged. The Programme Evaluation Organisation of the Planning Commission in its report submitted to the Rashtriya Barh Ayog states, "On the negative side, the continued rise of riverbed has created problems of seepage and drainage congestion, aggravating the waterlogging problem of the protected area, particularly in a strip along the eastern flood embankments."[5].

Most north Bihar rivers and, in particular, the Kosi, Kamla-Balan and Adhwara group, have a shifting nature. The Central Water Commission states that embankments along Kosi have at best served to jacket the river and, thus, prevent inundation of nearby land. No efforts have been made to identify a stable regime for the river and channelise it into this course. Unless this is done, the river would continue shifting its course within the embanked area and attacking the embankments. The incidence of breaches has been very high in north Bihar embankments[137].

Apart from the technical flaws in the policy of embank-

Shifting river beds



Many Himalayan rivers transport tremendous amounts of sediments as they have steep courses. When the course flattens abruptly in the north Bihar plains the river is forced to shed most of its silt which ultimately chokes the channel and forces the river to change course. Most of the north Bihar plain has been built up in this fashion.

INGLORIOUS FATE

The Kamla Balan plain in Bihar, once the land of Raja Janak, an extremely rich and fertile region, with a glorious history and tradition behind it, is today a land of misery. The legend has it that tilling the soil here could give birth to a Sita, the goddess of plenty.

Flood control measures have reduced floods but they have also disrupted the fertility cycle. Other factors like a rapid increase in population have resulted in fragmentation of holdings, in some cases, to levels far below the carrying capacity of the land.

Mango orchards and grasslands have been replaced by rapidly expanding farmlands which have even engulfed the numerous water bodies which dot the region. As a result, while embankments have aggravated waterlogging in a region where streams aggrade at phenomenal rates, a reduction in the flood cushion has compounded the problem. Change in land use patterns have been complemented by an increase in population. In certain villages more than 85 per cent of the population is tilling farmlands insufficient to support them (see table).

The Kamla Balan plain lies in the two districts of Darbhanga and Madhubani. It once formed the heartland of the famous Mithila kingdom and was a thriving centre of the Gupta empire. During the postindependence period, successive five year plans attempted to build an infrastructure for intensification of agriculture.

The region has numerous abandoned river channels. Three relief features exist, namely chaurs (depressions in which river water collects), high river banks and gently sloping plains, all of them the result of river action.

During monsoons, all rivers carry enormous silt loads. The pace of silt deposit has accelerated as all rivers have been embanked. Consequently the spread of silt, which earlier enveloped a large area, has become restricted. An accidental breach in an embankment now leads to catastrophic results.

Preembankment stage

"Prior to the construction of embankments, the shifts of the Kamla channel were a regular feature. A large number of dead courses of streams which flow sluggishly during monsoon rains are mostly known as Kamla. These shallow dead channels get flooded during rainy season, sometimes flow for a few days," writes Bhagalpur university geographer, Ganga Prasad Jha[3]. The Bagmati, the Kamla and the Bhutahi Balan are known as the Adhwara group of rivers. The special features of these is transfer of flood waters from one river basin to another, for example, the flood discharges of Bagmati flow into the Burhi Gandak. The rivers keep changing courses. Records show that the Kamla used to flow 15 km east of Madhubani, then 15 km west. Now it flows only 3 km east of Madhubani. The plain has been built up by the rivers Kamla and Balan and their small streams. The river divides are almost indistinct as a result they change course very frequently. During floods a river may join another. Hence the same name is given to several streams. Joint names are also common, there are many Kamlas and many Balans. When the river bed is sufficiently raised up by siltation the river changes course. The new course is soon filled up and the process is repeated.

Population pressure on land

Village	Population Density (person per ha area owned by villagers)	Per capita min area needed (ha)	% not owning min land needed %
Lalpur	3.41	0.18	39.0
Gausa	4.32	0.19	39.0
Maksudpur	11.51	0.20	87.60
Gadari	5.43	0.23	86.60
Gorhail	9.41	0.18	90.40
Tariyati	4.37	0.19	59.30
Tamoria	13.11	0.17	97.00
Chandradih	6.07	0.19	78.80
Bhutaha	4.40	0.18	44.00

Source: 3

Change in land use patterns

Village	Per cent of total village land (1897-1900)			Per cent of land (1970-1971)		
	Farms	Orchards	Wetlands	Farms	Orchards	Wetlands
Lalpur	56.07	22.16	19.01	86.11	4.54	6.47
Gausa	79.98	5.49	4.41	88.78	1.24	4.48
Maksudpur	81.88	4.62	4.82	84.60	0.92	4.82
Gadari	83.32	8.01	0.98	93.05	0.63	0.98
Gorhail	63.68	3.69	19.40	78.28	1.22	7.46
Trivati	77.40	9.65	10.19	85.20	1.02	6.88
Tamoria	72.36	10.69	2.36	84.68	1.46	1.74
Chandradih	91.48	0.84	3.96	94.77	0.38	1.02
Bhutaha	87.37	2.44	2.25	88.50	—	2.25

Source: 3.

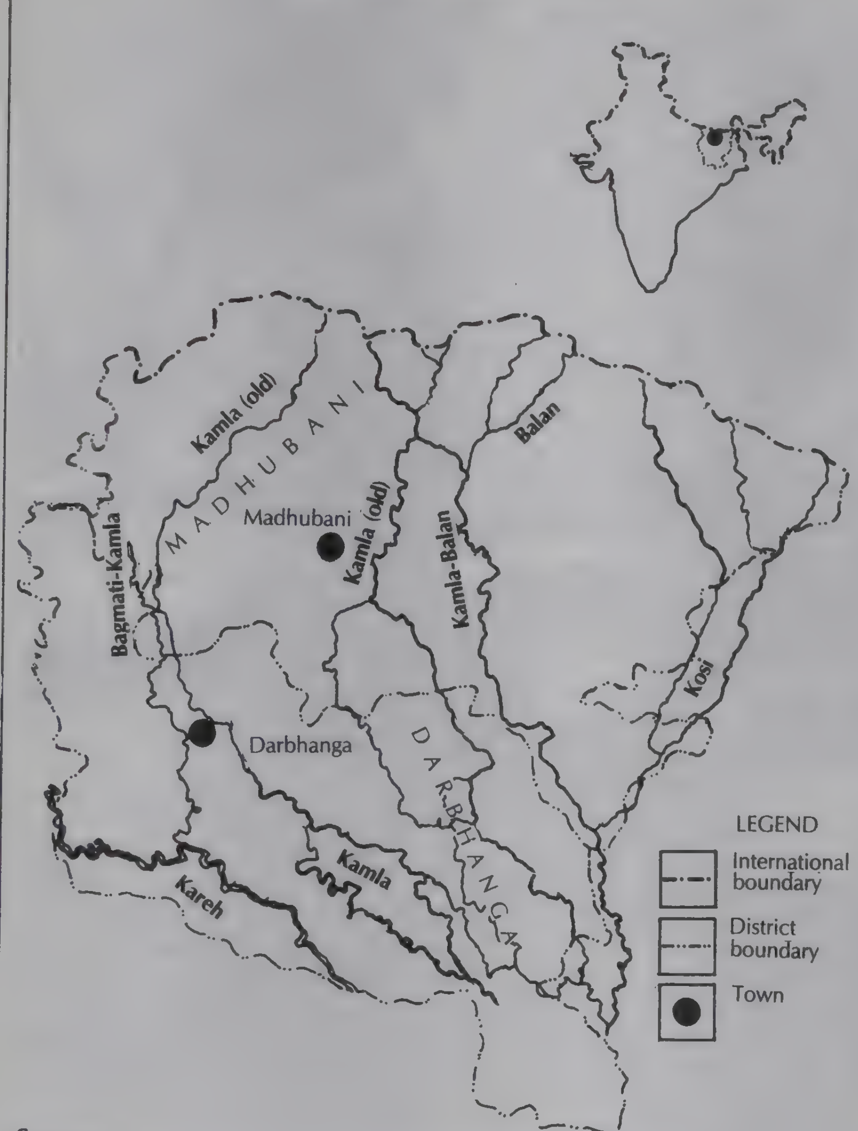
Stream density

The density of streams throughout the region is extremely high. Almost every village has a stream in or around it, some perennial. In the northern section if one counts rivers and rivulets from river Dhaus in the west to Panchi in the east, a stream can be found, on average, every 300 to 250 metres. Dead river courses, oxbow lakes, abandoned channels are numerous and the process of aggradation is continuing in all streams.

Silting up of river courses in the lower reaches is common. Embankments are unable to withstand the pressure of the large volume of water that has to be discharged in the monsoon and breaches are frequent.

An 1854 British report mentions floods even in the mid-19th century but the impact was probably not so intense then. According to Jha, a number of bunds were constructed later on and the flood severity increased. Bunds have caused great danger to villages situated in lower reaches. If flood waters enter the lowlands either by overtopping the embankment or through a breach, the water stagnates for months. About 30 years back, floods were confined to the western and southeastern parts of the region. Currently no area can claim immunity from floods,

The Kamla Balan Plains



The problem of shifting courses is also characteristic of Kamla and Bagmati. During this Century the Kamla has changed course thrice. The Bagmati made its last shift a decade ago when an already constructed 32 km long embankment on both sides had to be given up.

adds Jha. The severe floods of 1974 covered some 1,52,538 ha and caused considerable damage to settlements and crops.

When in spate the embanked streams become a terror. A fickle stream like the Bhutahi-Balan develops turbulent currents fast enough to sweep away wild elephants. It inundates vast areas, breaches embankments and shores up massive dumps of silt. The Bagmati-Kamla presents a similar horrifying sight. During a train journey from Hayaghat to Nirmali, in the monsoons, travellers can often see only tree tops and a few settlements on higher grounds.

Land use pattern

The net area sown accounts for 70 per cent of the Kamla-Balan plain. The area is devoid of forests. Local people depend upon neighbouring Nepal for timber. Population pressure is high. Agricultural land in Lalpur village shot up from 56 per cent in 1898-99 to 86 per cent in 1970-71. It encroached upon orchards and grasslands which shrunk from 22 per cent to 4.5 per cent and several water bodies were destroyed in the process as fields crept into chaurs and tank beds reducing their area from 19 per cent to 6.5 per cent (see table).

Till 1968 floods of high magnitude were caused by the overspilling of rivers. However, after embankments were put up, depressions and lowlands get flooded by rainwater, which cannot drain off into the rivers. In Gausa village, more than three-fourths of the area gets flooded and because of poor drainage becomes waterlogged.

Loss of fertility

According to Jha, complete control of the floods, howsoever laudable, is not an unmixed blessing. Enrichment of soil fertility has now stopped and villagers frequently complain of diminishing fertility[3]. This combined with a steady and accelerating population growth can mean a further deterioration in the situation.

How long the embankments which have been created will remain effective is debatable. Undoubtedly the once proud land of Raja Janak is today in the grip of a major crisis.

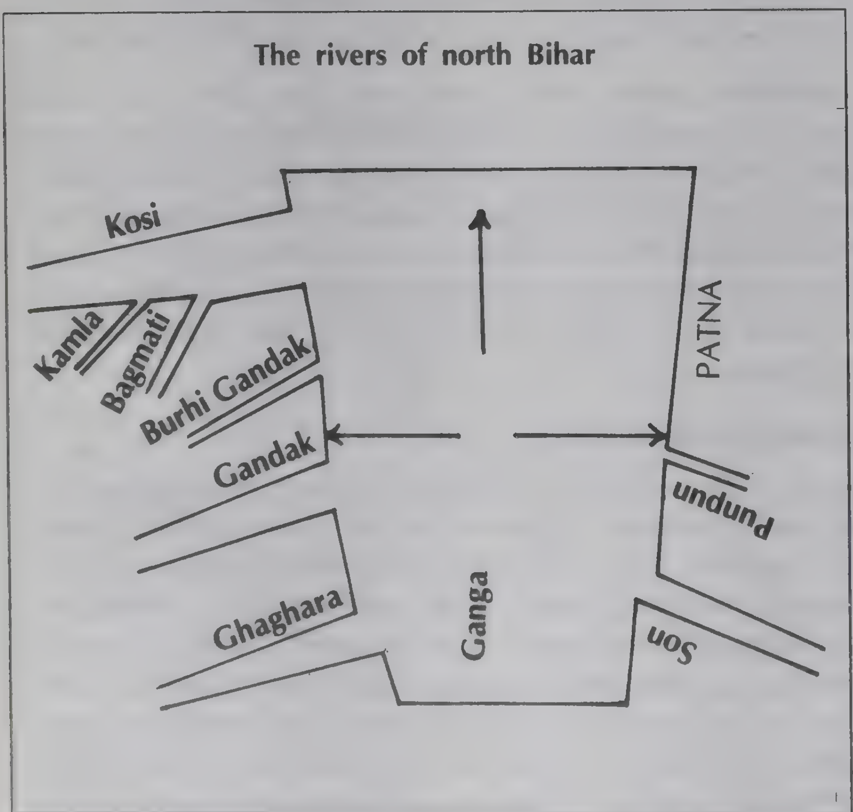
ment construction, the problem is further aggravated by the lackadaisical manner in which they are actually built. Technical specifications require a minimum distance between the two banks of any embankment. However, local political pulls and pressures often result in design specifications being altered to suit parochial interests, thus, reducing the margin of land between the river and the bund. This change in location often also disregards the natural flow pattern of the river. Consequently, these tracts become more vulnerable to the erosive action of the river and are more liable to be breached.

In Saharsa district, abandoned construction work can be seen along the originally mooted line on the Kosi. Faulty materials often used by profit hungry contractors results in breaches even at flood intensities lower than the rated capacity. This kind of corruption is commonplace in Bihar. The culpability of the state administration, particularly its technocratic establishment, also leaves a lot of room for doubt. *The Hindu*, for instance, stated that one of the three factors responsible for the floods of 1987 was "a deliberate and willful failure on the part of the irrigation department engineers to maintain the embankments, particularly at unbearable points which give way year after year with clockwork regularity." In league with contractors, the state government channelises the funds for repair works in such a way that by the time repair work is undertaken, the next monsoon and the next floods are already there, thus, offering the contractors and their wilful conspirators an ideal cover to claim full credit for work which was only partially undertaken.

Drainage congestion

Flooding in north Bihar has been further compounded by the acute drainage congestion that has come to characterise this region. Apart from embankments, communication networks like roads and railways, which have inadequate provision for waterways, have played a major role in creating this problem. All major roads and railway lines run from east to west, thus, cutting across the natural drainage as the rivers flow from north to south. Inadequate waterways on bridges build up the volume and velocity of flood waters. Both upstream and downstream of the bridge, the river attacks its banks with added fury, eroding it and subsequently inundating the adjacent countryside. Not infre-

HUNGER STRICKEN: Children gather snails for the pot. In some parts of Saharsa district, the problem of surface drainage congestion has become so acute that people have to use boats to perform their daily ablutions and survive on snails. (Krishna Murari Kishan)



North Bihar plains are drained by an extensive network of rivers most of which flow into the Ganga

quently, bridges are washed away. The inadequate waterway on the railway bridge near Jhanjharpur has caused breaches in the adjacent embankments year after year and at the same place, both upstream and downstream of the bridge, according to local activists[139]. The six bridges over Bagmati with waterways of varying dimensions, have had a lot to contribute to the inundation of the adjacent countryside, says Basawan Sinha, a retired chief engineer of the state's irrigation department.

The inadequate provision of culverts on roads and railways has also aggravated drainage congestion. Flood waters remain in the fields long after the actual flood. Since the groundwater table is already high, this leads to permanent waterlogging and salinity has become an imminent danger over considerable tracts. The restoration cost alone for national and state highways and rural roads damaged in 1987 stood at Rs 115.5 crore[126]. Even the canals that have been laid out in the region cut across natural drainage and they, too, have inadequate cross-drainage works. Thus, they have also contributed their bit to drainage congestion.

The laying out of roads and railways was undertaken by the British who, given the short term economic interest,

DEEP WATER PROBLEMS

North Bihar is interspersed with interconnected depressions known as *chaurs*. Frequent shifts in river courses have left deep depressions in the alluvial plains often termed as *mand*. Gradual siltation reduces the depth of such local depressions. Mands in due course become chaurs (deep water lowlands), which in turn get converted over a period of time to *chauris* (shallow lowlands). A farming systems research programme is being carried out in Talgarha chaur of Vaishali district by scientists of Rajendra Agricultural university and L N Mishra Institute of Economic Change and Development.

Chaurs are saucer shaped depressions with usually great differences between one chaur and another. Chaur farmers face two problems — drainage of water during *kharif* season and irrigation of crops during *rabi* and *zaid* seasons. Vagaries of the monsoon, uncertainties of water inflow into the chaurs, and their interconnectedness defy any simplistic solution to water management in the chaurs.

Studies show that the local inhabitants have a good understanding of the chaur ecosystem. If properly facilitated, these farmers not only arrive at a consensus about their problems, but they can also map an area as large as 4,000 ha with great precision. The farmers also recognise the need for collective action and the inability of some of the public agencies to comprehend the magnitude of their problems.

The interconnected chaurs of Vaishali district receive water from rainfall, and from floods in the Gandak and the Ghaghara. But in recent years the natural drainage courses have been impeded due to illegal deepening of ponds, construction of embankments, and non-completion of alternate drainage channels. Of late, waterlogging has become a serious problem. The water inlet into Berai, Talgarha and Belkunda chaurs can no longer be regulated.

The Gandak Command Development Authority (GCDA) has proposed an irrigation canal to reach Berai and Talgarha chaurs. Farmers are unanimous that this would add to their woes. Solutions must go beyond development of water resources, they add.

The interlinked hydrology of a chain of chaurs gives rise to a complex, diverse and high risk prone ecology. Indigenous cropping technologies have evolved over the years through farmers' informal experimentation. However, increased population pressure and human interventions have impeded the natural drainage of interconnected chaurs which, in turn, has led to great fluctuations in the water level from one year to another. In a typical chaur, the water level may range between 0.25 m to 4 m. Flash floods and protracted waterlogging has, of late, changed the microenvironment of the chaurs.

Farmers of the chaur are desperately looking for opportunities to diversify their enterprise mix to minimise the effects of ecologically induced risks. But, in the absence of institutional support to effectively link trade, technology and credit, enterprise diversification has not been able to go far. A lasting solution will call for collective action involving local farmers, relevant government departments, voluntary organisations and agricultural researchers.

Until now most interventions have been made without any reference to the complex set of problems that the chaur farmers face. In a paper on *'Sustainable Agricultural Development in Chaurs'*, Ajay Kumar, K C John and S Sharan, describe their discussions with Talgarha chaur farmers about how deepwater sugarcane was eased out of their cropping system because of commercial interventions.

Talgarha elders claim that sugarcane has been cultivated in the chaur from time immemorial. *Burrokh*, a variety of sugarcane, and *dharmi jagar*, a variety of rice grown in deep water conditions, were cultivated intensively in the chaurs. They used to follow a burrokh-dharmi jagar rotation in alternative years. Burrokh could elongate as the water ievel rose and survive continued waterlogging. But, as the water receded, the plant would not lodge. Farmers could harvest the sugarcane even under submerged conditions with the help of boats. Though burrokh could also be grown in upland conditions, its performance was relatively superior in a water regime of 1.25 m to 1.75 m. It could yield in the range of 10-20 t/ha. Farmers vouch for the quality of *gur* made from burrokh.

The local farmers distinctively recollect 1942 as a watershed in sugarcane cultivation. Many of them switched to new improved varieties of sugarcane popularised by the Sugar Factory of Sheetalpur (SFS) established in 1934. The factory had a catchment spread from Shiloth in Muzzaffarpur district to Sheetalpur in Chapra district. The sugar factory at Sheetalpur did not collect burrokh, as its sucrose content was low. Instead, it organised large scale distribution of new planting materials for farmers. It also provided an interest free loan against future harvests. The new varieties could not be cultivated in deep water. Discontinuance of burrokh, due to discouragement by SFS, made a significant shift in the local cropping system. Sugarcane-rice rotation was discontinued in deep water conditions. Dharmi jagar became the only crop, while sugarcane cultivation was confined to the upper periphery of chaurs.

The farmers had to discontinue the cultivation of sugarcane also because, under the Sugar Factory Control Act, each sugar factory had a notified area — the reserve area — in which no individual could use mechanised cane crushing on a large scale. With the discontinuation of burrokh, farmers discontinued gur making.

But, in 1950, SFS shifted to Garaul, 65 km away, because of severe losses due to floods. Till 1939, SFS organised collection of sugarcane through middlemen. Farmers had to go to Sheetalpur for collection of payment. In 1938, Bihar Sugar Factory Control Act was promulgated and it envisaged abolition of middlemen. It encouraged the formation of cooperatives of sugarcane growers. Sugar factories had to route their promotional schemes such as crop loans through the cane cooperatives. The factory abolished the crop loan scheme with the advent of cooperatives. Credit was advanced with a high interest rate. Cooperatives also got discredited because of irregularities. Farmers started to register directly with the sugar factory as *benami*. In the process, cane cooperatives were forced to wind up.

Inefficient management and continued losses, forced the sugar factory itself to close during the period 1968 to 1973. In 1974, the Bihar Sugar Corporation took over its management but failed to organise cane collection properly. Enterprising farmers would hire tractors at a rate of Rs 200 per tractor per day to carry sugarcane to the factory gate but the queue at the factory gate increased and farmers were stranded for five to seven days. At times, the hiring charges for tractors could hardly be recovered from the sale of sugarcane. Payments to farmers became irregular, several of whom did not receive their dues for two to three years. The farmers responded by discontinuing cultivation of sugarcane. Now the factory is closed due to shortage of sugarcane.

Meanwhile, the local farmers have not been able to harvest their main crop — deepwater rice — for four years in succession. This has created untold misery for the chaur people. They are diversifying their crops and experimenting with new crops in risk free periods. They are thinking of sugarcane again. A couple of farmers have started experimenting with a sugarcane variety which can tolerate protracted water stagnation. But will they invite legal attention for violation of the'reserved area' stipulation?

Ajay Kumar, K C John, S Sharan
Rajendra agricultural university,
L N Mishra Institute of Economic Change and Development

FAILING MEASURE: The process of digging and shifting earth to construct embankments is a continuous one in Bihar. In the last 35 years, about 3,400 km of embankments were constructed costing Rs 375 crore and Rs 475 crore were spent on their maintenance. Nevertheless, the flood prone area shot up from 2.5 mha to 6.4 mha and embankment failures have assumed unmanageable proportions.(Krishna Murari Kishan)

spared little time for details like country drainage. The independent Bihar government instead of correcting this anomaly has, in fact, extended this colonial legacy. Political patrons, in order to woo their vote banks, have pushed haphazard sanctioning of roads. The urgency to get these works completed before the onset of the next elections has often led to a neglect of proper surveys.

Indifferent occupation of the flood plains is another major factor leading to drainage congestion. The area has a phenomenal population burden. The population density is as high as 640 persons per sq km and almost 80 per cent of the people are engaged in agriculture and related activities. The pattern of land holding is extremely inegalitarian. Political leaders, rather than enforcing land reforms through redistribution of private lands, have opted for myopic alternatives like use of *gairmajarua am* land (common land under governmental control) and, in many instances, even notified drainage channels for the settlement of the landless. Numerous depression tracts, which had served as natural detention basins, have been reclaimed over the years leading to acute drainage congestion and multiplying flood damage costs as more human settlements

DISRUPTED TRAFFIC: Communication networks like roads and railways contribute to the problem of drainage congestion in the state. Flood waters often wash away the structures supporting railway tracks and disrupt traffic for days.(Vikram Kumar)

are now situated in floodways.

The system of interlacing channels *(dhars)* which had been characteristic of the riverine regime of north Bihar, had contributed greatly towards siphoning off the flood waters in the main channels. They had also helped to drain the precipitation in the river's neighbouring catchment. However, with the construction of embankments, roads and railways, the flow of these streams has been impeded and they have fallen into disuse. Their role has also been impaired by local vested interests who have controlled their natural flow for agriculture and fishing. Consequently, nature's gift towards flood abatement and drainage decongestion, which played a significantly ameliorative role, has fallen victim to human intervention.

FLOOD PROTECTION: AN ASSESSMENT

An objective statement, sustained by hard data, which evaluates the flood control measures undertaken in Bihar is difficult to come by. The Rashtriya Barh Ayog had sought information from the states to evaluate the performance of embankments. But the commission drew a blank as most states, including Bihar, were not forthcoming with adequate responses. Consequently, the report could not evaluate the performance of individual embankment projects.

Though many years have passed since the report was published, the situation remains more or less the same. Government documents do admit to the various facets of the flood problem but there is no attempt to bring out the interrelation of these different facets. Though drainage congestion is highlighted in the relief commissioner's report for the year 1987, no attempt is made to get into the causes

UNFAIR SETTLEMENT: Those displaced by floods and waterlogging have to settle down on embankments but while they offer some relief from the growing menace of the rivers the loss of a home is hard to be compensated for. (Amar Talwar/CSE)

from which it stems. While siltation is stressed as an important aspect of the problem, no attempt is made to explain its likely impact on the river bed in case of embanked rivers. Inundation is related to excessive precipitation. The mounting cost of anti-erosion works due to shifting courses is conceded but little effort is made to evaluate the sagacity of embankment construction in a situation like this. Breaches in embankments and canals are enumerated but their causation is attributed to the excesses of nature. The problem of waterlogging is admitted in the major irrigation schemes but it is made out to be a managerial crisis rather than an environmental one. Indifferent occupation of the flood plains is linked to population growth but not the political factors favoring it. These reports though quite disparate at one level display a consistent focus at another. There is a never tiring effort to rationalise the measures taken till date. Their persistent effort is to place the blame squarely on the unpredictability of natural phenomena and, to the extent human accountability is to be considered, on the shoulders of Nepal.

While fully recognising the data deficit that exists, an entire spectrum of opinions ranging from unwitting governmental admissions to old government records, newspaper reports and the perceptions of the affected population does show that the Bihar government's flood control policy is more misplaced than merely inadequate and has led to counterproductive results.

The available data clearly shows that flood control measures have been ineffective. North Bihar districts, despite all efforts, continue to get flooded regularly (see table 46 to 48). The figures of the flood prone area in north Bihar reveal certain very interesting facets. As per the figures contained in the RBA report, 2.50 mha were flood affected in north Bihar in 1954. The draft annual plan 1988-89 for irrigation and flood control of the government of Bihar places the flood prone area at 6.46 mha. This is 37.24 per cent of the geographical area of the state (17.35 mha). But this report glosses over the magnitude of the problem in north Bihar. Of the 6.46 mha that are flood prone, 3.78 mha fall in the north Bihar plains (see table 49). This does not include the flood prone area in the Ganga basin which is put at 1.13 mha. Given the fact that the Ganga floods areas on both its banks, some 0.4 mha can be conservatively added to the estimate for the north Bihar plains. That would make the flood prone area of north Bihar to be 4.18 mha. In other words, almost 65 per cent of the flood prone area of the state lies in north Bihar. As north Bihar has a total geographical area of 5.24 mha, this means nearly 80 per cent of the north Bihar plains are flood prone (see table 50).

The RBA report further states "By construction of 2,951 km of embankments in north Bihar and 487 km in south Bihar, that is, a total of 3,438 km and some channel improvement works, about 2.73 mha in north Bihar and 0.18 mha in south Bihar (that is, a total of about 2.9 mha of flood prone area) has been given some reasonable degree of flood protection." Thus, out of a total of 4.18 mha of flood prone area in north Bihar, 2.73 mha have been given a reasonable degree of protection. This leaves 1.45 mha as unprotected. In 1987, 3.12 mha were affected in the state

Table 49

Flood prone area of Bihar

River basins		Flood prone area (mha)
North Bihar rivers		3.777
of which Burhi Gandak	0.821	
Gandak	0.500	
Bagmati	0.322	
Kosi	1.015	
Mahananda	0.515	
Kamla	0.370	
Ghaghara	0.234	
South Bihar rivers		1.557
of which Son	0.370	
Punpun	0.613	
Kiul & Harohar 0.356		
Chandan	0.113	
Badua	0.105	
Ganga		1.127
Total		6.461

Source : 133.

Table 50

Flood prone area of north Bihar

Geographical area of Bihar	17.35 mha
Flood prone area of Bihar	6.46 mha
of which in north Bihar plains	3.78 mha
in Ganga basin	1.13 mha
Total flood prone area north of the Ganga in Bihar	4.18 mha[1]
Per cent of flood prone area of Bihar (%)	65
Geographical area of north Bihar	5.24 mha
Per cent of geographical area flood prone in north Bihar (%)	80

Note : [1]Given the fact that the Ganga floods areas on both its banks some 0.4 mha can be conservatively added to the estimate for north Bihar plains which makes the total flood plain area of north Bihar plains to be 4.18 mha

Source : 133.

until August, of which 2.47 mha were affected in north Bihar. Even if one takes the entire unprotected area (1.45 mha) to be flood affected, that still leaves 1.02 mha of protected area as being flood affected. This accounts for an almost 40 per cent failure of the flood protection works in north Bihar.

Another important factor that the draft annual plan document tends to gloss over is the gravity of the high incidence of flooding in north Bihar. North Bihar accounted for almost 80 per cent of the flood affected area in the state in 1987. This pattern was probably the same in earlier years.

The above discussion also shows that the flood prone area in the north Bihar plains has gone up phenomenally — from 2.56 to 4.18 mha — since 1954. The draft annual plan itself admits "Despite this amount of investment, flood damage continues to be a major problem of the state." But the report only calls for more and higher embankments: "It may be mentioned that the policy laid down by Government of India is that the embankments should be designed in urban and strategic location for a 100 year flood and in other cases for a 25 year flood. This means that the embankments are not intended to provide protection beyond a specific magnitude of flood." The report also adds, "The major rivers of north Bihar originate far away from the northern border of the state, in Nepal. Long term measures of flood control such as construction of storage reservoirs with earmarked flood cushion are thus possible only if such measures are permitted to be located beyond the border of the state (in Nepal). This is one of the reasons due to which the flood control measures in the flood prone region of north Bihar had to be limited to only short term measures"[126].

The policy of embankment construction is, thus, sought to be rationalised on the plea that until efforts are undertaken to build dams in Nepal, such a policy, perforce, has to be taken recourse to. Meanwhile, embankment construction is facing more and more financial constraints. With constructed embankments failing to control floods, more and more money is being used to repair, widen and elevate the existing ones. Consequently, the pace of extension of flood protection works has come down considerably. As the relief and rehabilitation commissioner's report states, "In view of the fact that 72 per cent to 75 per cent of the outlay on flood control gets spent on the new anti-erosion works or their repairs, it is difficult to provide funds for the protection of additional areas." Non-completion of embankments further aggravates the problem of flooding in non-embanked sections both upstream and downstream of the embanked section. Therefore, the relief and rehabilitation commissioner's report argues, "the spill of the river up in Nepal bypass the embankment and inundate protected area in Bihar. This necessitates continuation of the embankments in Nepal up to the uppermost spilling reach." A report in *Hindustan* speaks of the manner in which incomplete embankments have compounded the problem of flooding in the Kusheshwar Sthan block of Darbhanga district. Bounded by Kamla in the west, Kosi in the east, Kareh in the south and Balan in the north, the problem of flooding in this block has been aggravated by the incomplete construction of the western embankment of Kosi and that of the northern embankment of Kareh[140].

The Bihar government is caught up in a financially insurmountable situation as far as its flood protection objectives are concerned. According to the draft annual plan (1988-89) for irrigation and flood control, government of Bihar, "the outlay approved for the Seventh plan is Rs 144 crore with a target to provide flood protection to an additional area of 0.15 mha by constructing embankments over a length of 125 km. This would have extended the total length of embankment constructed from 3,396 km to 3,521 km and the area protected from 2.88 mha to 3.03 mha." The actual expenditure was more than the approved outlay

MISERY IN MALDA

The government of West Bengal thought in the 1960s that it would be a good idea to control floods by straitjacketing the state's numerous rivers. Now less than two decades later many in Malda are being forced to consider whether it was indeed such a good thing.

So many rivers criss cross West Bengal that the state is known as the 'evacuation channel' of northern India. More than half of its area is flood prone[1]. The Ganga and several of its tributaries flow through the state before falling into the Bay of Bengal. Numerous efforts have been made to control floods in West Bengal through dams and embankments. But a study conducted by Sumantrao Mukherjee, now reader in geography at Vishvabharati university, reveals the negative effects of embankments on Malda district in central Bengal[2].

Girdled by the Ganga on the south and southwest, Malda has Phulahar in the west and Punarbhaba on the east. Mahananda enters it from the north cutting the district into roughly two halves. Shrimati and Tangaon also enter the district from the north and flow into the Mahananda.

Malda is made up of the flood free, relatively higher Barind tract towards the northeast, and the low lying *tal* and *diara* areas towards the south. The spill of the Ganga, Phulahar and Mahananda used to inundate the tal area almost every alternate year. The area is highly fertile and suitable for mango groves. The diara region is, however, the most fertile tract. It was built up by the silt brought down by Ganga whose old channel can still be traced. Nearly half of the district used to get inundated annually and, in high flood years, almost two-thirds. Local rainfall was rarely the cause of floods, but the swollen river bringing water from distant catchment areas.

In 1972, the government decided to build embankments along the Ganga and the Mahananda to control floods. This turned out to be a mixed blessing. Agriculture has grown in the district and many farmers now get three crops a year. But before the embanked phase, floods used to moisten the soil and help in *rabi* cultivation. Now the land remains dry round the year. The silt charge from the floods has also disappeared, leading to a steady decline in fertility. All this has increased the cost of cultivation.

Drainage congestion has become another problem. Local drainage channels dried up after the embankments were built. People even started cultivating them. Now when there is heavy rainfall locally, these channels cannot drain away the water.

Local rainfall even causes drainage congestion in the area on the riverside of the embankments, which were built about one km away from the river banks. These banks are usually higher than the surrounding countryside. Rainfall therefore gets trapped between the river banks and the embankments. Erosion of banks is another serious problem especially with the Ganga.

The large number of *bils* and low lying depressions in the tal and diara areas used to collect the spill waters of the rivers during the monsoon. Cultivators would often use this water for rabi sowing. In the postembankment phase, these depressions dry up soon after the rains.

Prior to embankments, the extensive fallow lands used to be full of tall grasses. But now they have been distributed to settlers as agricultural lands. This has resulted in a scarcity of grazing land, which often creates law and order problems.

Now that the countryside no longer gets flushed through annual floods, several health problems have also begun to emerge. To make matters worse the acquisition of land for embankments has turned numerous farmers into landless workers.

in each of the first three years of the plan. The plan already considers it necessary to revise the expenditure on the flood sector in the Seventh plan to about Rs 300 crore. While the anti-erosion measures for the Kosi embankments and the Piprasi-Pipraghat embankment on Gandak, which were to be completed before the 1987 floods, were estimated at Rs 25 crore and Rs 20 crore, respectively, works for Rs 15.03 crore and Rs 10.13 crore only could be executed due to insufficient financial resources[133].

Thus, flood protection works have proved unsuitable not only on technical and environmental grounds but also their financial viability is an impossibility. However, it offers to the state a self defeating cyclic logic. Responsibility for failure of flood protection works can always be pinned on inadequate investments without forcing the government to look for a new policy for flood control. Dissent is mellowed by playing up the Nepal factor, namely, stressing that deforestation in Nepal is responsible for the excessive siltation in north Bihar rivers, and that storage reservoirs in the Nepal Himalaya are the only viable solutions to the problem. The scientific evidence of a strong link between deforestation in Nepal and floods in north Bihar plains is at best tenuous. The reclamation of Terai swamps in Nepal may have affected the current status of floods, though again the evidence is scanty as this is a very under researched area. C C Patel, irrigation secretary in the Union government, has recommended, "No large scale reclamation of swamps, *bils*, *chaurs* and *tals* (which act as detention basins) should be undertaken as this would cut off most valuable valley storage which has been moderating the floods"[141]. Unfortunately, research in this field is totally inadequate.

Dams: the panacea?

The state government has been advocating the need for storage reservoirs in the upper catchment of the north Bihar rivers as the only true solution to the problem of flooding in the state, which will bring the attendant benefits of power generation and canal irrigation. Cumulatively, these benefits would relieve north Bihar of its proverbial backwardness. Unless efforts are undertaken in this direction, it will perforce have to stick to short term measures like embankments.

The state government has identified dam sites in Nepal but claims that only the Central government can negotiate with Nepal. These sites have been identified at Nunthore on the Bagmati, at Shishapani on the Kamla and at Barahkshetra on the Kosi. Even the opposition parties, otherwise extremely critical of the state government's flood control policies, share an identical perspective on the issue of high dams. Their criticism is basically limited to accuse the state government of not being persevering enough. Typical of this is communist politician Bhogendra Jha's booklet on the floods issue and particularly the foreword to it written by A Dasgupta, a retired chief engineer of the

irrigation department in Bihar, which admits that attempts to contain the rivers by construction of marginal embankments have met with little success. Dasgupta states, "The river swing still continues and the protection measures have been annually draining out huge amounts from the public exchequer. Breaches have now become a common feature. The solution, therefore, lies in construction of storage reservoirs in the upper catchment in the hills of Nepal"[131].

The earliest drive to construct a high dam on the Kosi dates back to 1945 when, as per the wishes of Lord Wavell, the then viceroy of India, A N Khosla, chairman of the central water and power commission, submitted the first scheme for river Kosi which envisaged the construction of a high dam for flood control and a barrage for irrigation. This was expected to moderate the flood flow to 5,600 cumecs and had also the potential to generate 250 mw of electrical power. The cost envisaged was about Rs 177 crore. This scheme was put before an advisory committee which dropped it because the dam proposed was in a highly seismic zone, the 20 year period of construction was too

THE TORTURED AND THE DAM: There have been many protests by the local people against the ineffectiveness of flood control works. In 1978 protests forced the authorities to suspend work on the Gandak canal project. The state government insists that only the setting up of a dam in Nepal will help solve the flood problem. Till then it will have to stick to measures like embankments. (Krishna Murari Kishan)

long, and the huge amount of cement required was beyond the capacity of Indian cement producing units. The advisory committee, however, recommended a low detention reservoir at Belka and a marginal embankment on the eastern side. However, this idea too had to be shelved as it was felt that it would be rather impossible to build a dam of about 30 m on sand foundation. Eventually, the Kosi project in its present form, without the inclusion of the high dam project, was formalised in 1954.

However, increasing failure of the embankment works, made the government revive the high dam issue in 1974 when the Kosi board was constituted with Kanwar Sain as its head. The board stated, "the time is ripe to take up the Barahkshetra dam project in hand. This project would give a positive solution to the silt problem, being experienced upstream and downstream of the Bhimnagar barrage. This project will also effectively reduce the highest peak floods to safe limits. It would provide a large block of power at a reasonable cost. The stored water could also be used for intensive irrigation in Bihar and Nepal"[131].

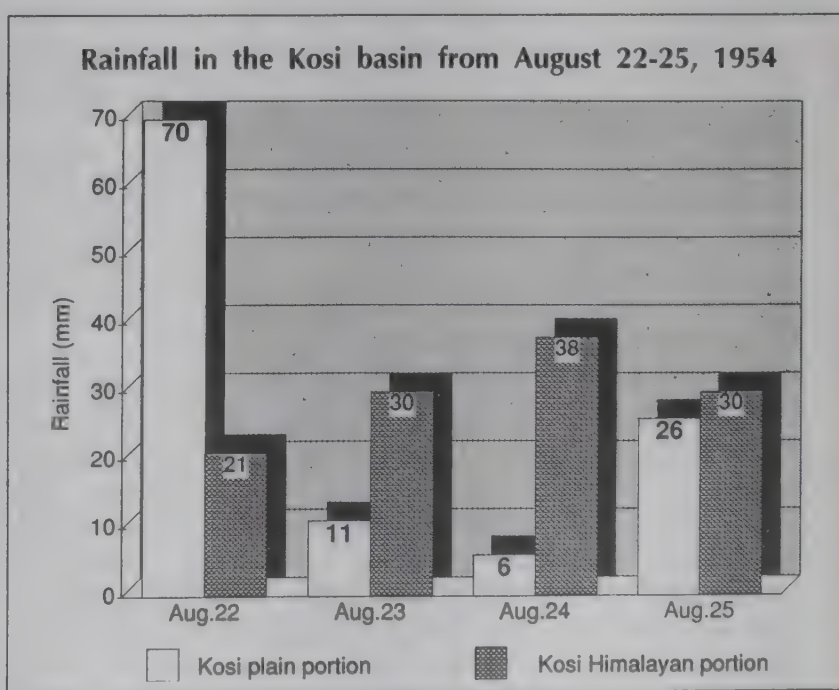
This was despite a statement by the chief engineer of irrigation and electricity department of the government of Bihar at a seminar in Sikkim in 1975 that, "there is a line of thinking to construct a very high dam to provide ample silt storage and space for moderating maximum flood from 23,800 cumecs to 5,600 cumecs. The various sites for such dams are Barahkshetra, Belka and Kothar. In case of Barahkshetra dam, it has been found that its location will be close to the epicenter of the past disastrous earthquake. No doubt, the techniques of construction of dams in highly seismic zones have been found out, but all the same the cost factor and political conditions have also to be taken into consideration. About Belka and Kothar dam sites, it has been found that relief provided by silt storage would not be commensurate with the expenditure, and hence these have not been considered suitable sites" [9]. A study carried out by the Geological Survey of India concluded that the proposed 155 m high dam across the Kosi at Kothar will silt up within a short period because of the heavy landslides in the catchment of Sun Kosi and Tamur[78].

Yet an updated feasibility report was prepared in 1981 and sent to Nepal in August 1981 and was raised during a secretary level meeting in February 1982. Meanwhile, views regarding the Shishapani and the Nunthore high dams were also formalised. Thus, the same project which at one time had been shelved, has been revived with an added and expanded vigor.

Apart from the seismic factor and the certainty of high siltation rates, the effectiveness of a flood moderation dam may also be rather low because of the large free catchment downstream. The flood prone areas in the lower part of the basin, where the flood problem is usually more acute, would probably get the least benefit of the effect. And if indeed there was a moderation of the frequency and intensity of floods, a further encroachment of the flood plains would take place in the lower basin. Consequently, a situation might arise when, even a moderate release of water during peak flow, in conjunction with water flows from uncontrolled catchment lower down, could lead to damages exceeding the prereservoir period. Multipurpose dams usually throw up several managerial problems. With the interests of electricity and irrigation being in conflict with those of flood moderation — and since priority is usually given to the former two interests — the flood control factor in the reservoir would be the main sufferer with grave consequences during periods of high flows.

Details provided by meteorologists O N Dhar and J Narayanan about the August 22-25, 1954 rainstorm which led to the unprecedented floods in the Kosi are indeed instructive. The rainstorm was due to the setting in of a 'break' in the monsoon which synchronised with the eastward movement of westerly waves. The result was vigorous monsoon conditions over north Bihar-Nepal Terai areas on August 22 and subsequently over the Himalayan areas of Kosi's catchment. On the first day of the rainstorm, the plains portion of Kosi's catchment received heavy rainfall (70 mm), which caused the rivers in the plains to rise considerably. On the second and third days, rains decreased considerably in the plains but increased greatly in the catchment of the three major tributaries, Sun Kosi, Arun and Tamur. All the three flood waves coming down from these tributaries synchronised at Tribeni to send down an unprecedented discharge of 24,200 cumecs at Barahkshetra that day, which coincided with already swollen rivers in the plains. The result was a disastrous flood. The last day both the hills and the plains received fairly heavy rains. Since both the hills and the plains received an equal amount of rainfall over the four days, Dhar and Narayanan concluded that "both parts of the catchment played their part in flooding the lower reaches of the basin"[142]. If the proposed dam were to be full at the time of such a rainstorm — and heavy rainstorms are not uncommon late in the monsoon season — sudden releases from the dam can cause immense havoc downstream.

The irrigation potential of proposed dams also raises



On August 22 the plains catchment of the Kosi received 70 mm of rainfall. For the next two days rain decreased in the plains but increased greatly in the Himalayan catchment. As the flood pulse travelled down to an already swollen river, both the hill and plain areas received heavy rain on August 25. An event which resulted in a disastrous flood.

MAJOR SETBACK

Modelled on the prestigious Tennessee Valley Authority (TVA) in the US and built with great expectations, the four dams of Damodar Valley Corporation (DVC), constructed in Bihar as the first major response to control floods in West Bengal, have failed to serve the purpose.

The Damodar, better known as the 'Sorrow of Bengal', rises in the Palamau hills of Chotanagpur hills in Bihar. Its catchment has been heavily deforested. British rule first brought settlements to forest clearings in the catchment. Land taxes being heavy, more and more forests were cut by the *zamindars* and converted into agricultural lands. In the early 1830s, the zamindars began to build embankments. In 1943, a year after the terrible famine, there was a catastrophic flood. Calcutta was cut off for 10 weeks. This was also the time when the Japanese were fighting in the Northeast. (Worried that war operations could suffer, the British governor general approached US president Franklin Delano Roosevelt who sent an expert of the TVA to visit the region. He suggested that eight reservoirs be built at various sites[1].

Only four dams were finally built after independence — Tilaiya in 1953, Konar in 1955, Maithon in 1957 and Panchet in 1959. A barrage was also built across the Damodar in 1955 at Durgapur. The two canals from the barrage irrigate the districts of Burdwan, Hooghly, Howrah and Bankura. The Tilaiya, Maithon and Panchet dams have hydel stations and numerous other thermal power stations have come up at various sites. By March 1979, investment in the DVC project was of the order of Rs 425 crore.

The Damodar is a shallow, wide and flashy river. Its upper valley has a catchment area of 1.73 mha. The lower basin is choked with silt. The river enters the plains below Raniganj and, near Burdwan, it abruptly changes course in a southerly direction. Later it bifurcates into two channels — the Damodar channel (also known as Amta channel) and the Mundeswari channel. The Damodar channel which is now silted up carries water only during high floods. The main flow passes through the Mundeswari channel which further branches into two loops. Ultimately, the river discharges into the Rupnarain and then into the Hooghly. Since the entire left bank of the river is dotted with important industrial towns, it has been protected by an embankment for long. But an attempt to protect the right bank was soon abandoned.

From 1950 to 1959, five floods with a discharge of around 18,400 cumecs (0.65 million cusecs) had been recorded. But major floods have occurred even with lower discharges. The 1943 flood recorded a discharge of only 9,911 cumecs but the left embankment breached at several places washing away railway lines to Calcutta and also the G T Road.

The design flood for the eight DVC dams proposed by the US expert was 28,300 cumecs (one million cusecs). The design flood for the post August 15 period was assumed to be 21,200 cumecs (0.75 million cusecs) because rainfall is normally lower in this period. Between Rhondia and the sites of the two dams at Maithon and Panchet, there is a large uncontrolled catchment. This catchment can produce a large discharge in case of heavy rains. The American assumed this would never be more than 7,079 cumecs (0.25 million cusecs) and that during a high flood, the peak flow from the lower area would have passed down the river by the time the upstream dams would get filled up and, consequently, discharges from the dams would not add to the flood.

It was envisaged that the Damodar river below Durgapur would never see a flood of more than about 7,079 cumecs (0.25 million cusecs). A system of several reservoirs was proposed to store 3,580 mcum. But because only four dams were constructed the actual storage could only be 1,860 mcum. In practice, even this could not be achieved, because the Bihar government could not acquire lands up to the top of the gates. Thus, the actual flood cushion is 1,280 mcum, about a third of the 3,580 mcum envisaged.

The Rashtriya Barh Ayog carried out a special study of the DVC and found that between 1958 and 1978, the discharge reached 7,000 cumecs only in 1959 and 1978. In both cases, heavy floods from the catchment area below the dams played a crucial role. In 1959, the peak inflow into the reservoirs was 17,641 cumecs and the outflow was only 8,155 cumecs. But the outflow at the Durgapur barrage was 9,911 cumecs, far more than the estimated safe capacity of about 7,000 cumecs. In 1978, the dams let out a peak discharge of only 4,615 cumecs and yet the discharge at Durgapur reached an all time high of 10,732 cumecs. The RBA report states that if there were no dams, an unprecedented flood of 33,414 cumecs would have been experienced at Durgapur and the whole industrial belt of Asansol and Durgapur and major portions of the districts of Burdwan, Bankura, Hooghly and Howrah could have been inundated.

Even the attenuated flood inundated Calcutta which was under a metre high sheet of water for many days and the districts of Burdwan, Hooghly and Howrah were badly affected .

It was an unusual meteorological phenomenon that caused the 1978 floods but it also exposed several design assumptions. The cyclone, which came in September, that is, late in the monsoon season, turned back towards the Bay of Bengal and deluged the entire catchment. Since it was late in the monsoon and reservoirs were relatively full, reservoir releases instead of reaching Durgapur after the flood from the lower catchment had passed, contributed to it.

The DVC dams contributed to the 1978 floods also through the steady deterioration they have caused of the drainage system below. Even before they were built, the condition of the lower Damodar was far from satisfactory. Its various spill channels were blocked with vegetation and silt. Below a place called Begunia, the river can carry only about 1,416 cumecs of water discharge. Therefore, moderation of heavy floods down to even 7,000 cumecs at Durgapur, as envisaged in the project, will not prevent floods downstream. The RBA noted that several problems have arisen in the lower reaches of the river after the construction of the dams. Over the years, the drainage capacity has gone down because of the continued silting of the river bed due to insufficient flushing. At the same time, the increased sense of security against floods has resulted in further encroachments into the flood plains.

The Lower Damodar Investigation Committee in 1956 had clearly stated that the conservation of the river channel must not be ignored. It recommended that concentrated flushing doses should occasionally be released down the river in the interest of conserving the channels. But the RBA found that only in seven years between 1958 and 1978, maximum outflows were above 4,248 cumecs and no studies had been carried out to assess their effectiveness on the downstream regime of the river[2].

According to Subrata Sinha, former deputy director general of the Geological Survey of India, "dams have proved to be more a curse than a source of prosperity, defeating their

purpose. During years of excessive rainfall, they have to be protected by releasing heavy discharges, which inundate downstream reaches, which now have reduced channel capacities due to lack of adequate round the year flushing by perennial river discharges."

Sinha also claims that the canals of DVC and other dams in the region have brought water to areas normally rich in groundwater, having a water table near the land surface. The additional irrigation water creates waterlogging. And during a year of heavy rains, or floods, there is no cushioning space left, within the groundwater aquifer, making the flood situation worse[3].

Not surprisingly, RBA reported that the West Bengal government did not agree to any more dams on the Damodar as it felt that more control will cause damage to the river regime and worsen the condition of the Rupnarain river and also affect the Hooghly river.

In fact, Kapil Bhattacharya, a civil engineer with the Bengal government had pointed out many fallacies in the DVC project. He had claimed that the dammed river will not be able to flush out the sediments. Instead, it would deposit silt in river beds giving rise to increased incidence of *chars* (river islands). This would adversely affect the flow of the Hooghly and the deep water port at Calcutta. A new port would have to be constructed further downstream. Calcutta's drains which flow into the Hooghly would become useless and sewage would have to be pumped into the low lying land in east Calcutta. As dredging would be both expensive and ineffective, additional water would have to brought into Hooghly by constructing a barrage elsewhere[4].

A lot of what Bhattacharya predicted has indeed come true.

several questions especially in the context of the under utilisation of the existing groundwater potential. As it is, as per one estimate, almost 35 per cent of the total cultivable land area gets waterlogged in north Bihar for a period ranging from three months to a year at different places[143]. In the light of the above, the Bihar government's plea for storage reservoirs not only appears to be facetious but even dangerous.

ALTERNATIVES

The intended and practiced flood control measures of the Bihar government have been grossly misplaced. Most of it has been characterised by a high degree of adhocism which over the years has gravely complicated the problem. Water expert M C Chaturvedi of the Indian Institute of Technology at New Delhi stresses the inefficacy of structural measures such as embankments and calls for an appreciation of "the unique physiographic-geologic-hydraulic features of the Himalayan Gangetic region, the world's highest and steepest geologically young mountain system followed by extremely flat alluvial land. The drainage system of the two, which are in dynamic interaction, have different hydraulic characteristics, hydrologic inputs and geomorphologic characteristics"[144]. Thus, in his opinion, any flood management system should compulsorily take note of this feature.

Existing attitudes delink nature from development while confronting the issue of flood control. Consequently, as observed by geologist Subrata Sinha of the Geological Survey of India, flood control measures had been characterised by an exclusive emphasis on "development by construction and not conservation," with the entire basin management being left to the engineers and their limited expertise. A suitable alternative has to be evolved with more active participation of geologists, geographers, foresters and social scientists[145]. S B Synghal, professor of civil engineering of M M M Engineering College, Gorakhpur suggests a careful management of technology so as not to obstruct the floods but to use the advantages of floods through better land use and planning. In other words, a river's natural regime should be given its due appreciation before embarking on any engineering response to contain it. This might often make flood plain management techniques more desirable to flood control measures[146].

Even the report of the Working Group on Integrated Action Plan for Flood Control has stated that within the limits of resources and time, floods cannot be controlled completely and efforts to make the rivers adjust to the requirements of humans would be prohibitively costly in terms of money, and, futile. The logic of realities, therefore, would point that beyond a certain stage, humans will have to adjust themselves to the ways of the river. This would simply mean that human settlements, public utility institutions and investments on land and water should be regulated keeping in view the flood hazard of the area concerned. Unfortunately, this is one domain where the Bihar government's enterprise has not at all been visible.

In Bihar, primary emphasis has been on flood modifica-

WATERY PRISON

There are very few voluntary organisations working amongst the flood affected people of India to understand their travails and perspectives. Among the few that do exist, the work of Samta Yuvjan Sabha, Sampurna Kranti Manch, Majdoor Kisan Sangathan and Mahila Jagaran Sangathan, who work in close coordination with each other, stands out in Bihar. These organisations have been regularly conducting campaigns to inform, educate and mobilise public opinion so that a sound flood control policy can be formulated. Their most recent campaign was a *padyatra* through Saharsa district in February 1989.

The marchers, found concrete evidence of how the Kosi project has become a curse for the region. The project was pushed through in the name of development without any concern for its ecological appropriateness or for the people who were displaced. About 300 villages were affected but people from only 47 were compensated and that too only for the land on which they had their dwellings and not the land they tilled. Official documents now themselves admit, according to the marchers that 182,400 ha have become waterlogged in the command area of the eastern Kosi canal and the Rajpur canal and another 14,800 ha along the western Kosi embankment. the consequence has been devastating for 192,000 people living in about 304 villages. Waterlogging has led to a significant rise in the groundwater table and permanent waterlogging has also polluted the groundwater. In several villages of Darbhanga and Saharsa district (Ujooa, Jhada, Ballia, Simar, Manovar and others), the water from hand pumps emits a stench. Consumption of this water has resulted in a high incidence of diseases. In these villages, for as many as eight months a year, people have to use boats even for their daily ablutions. Inhabitants of several villages — Samani, Jalay, Brahanpur and others — stated that they had to survive on non-edibles like snails.

The padyatra commenced from Ujooa village in the Kushehwar block of Darbhanga district. The village lies between Kosi and Balan and suffers the ravages of floods almost every year. The marchers split into small groups with each conducting a door to door survey in different villages to collect data and involve the villagers in a dialogue about their problems. After Ujooa, the marchers passed through Tegachha, Hirnahin and Simrahim villages, which have serious problems of waterlogging, drinking water and diseases of various kinds. In village after village — Dhudha, Jamalpur, Manovar, Ghoghonpur — the local people held the embankments responsible for their woes.

In Ghoghonpur, in fact, the people claimed that in 1988 a breach in the embankment had facilitated the draining off of flood waters and thus averted the problem of waterlogging. At the same time, the fertile deposits left behind by the waters has given them a rich harvest. Consequently, they argued that if embankments were done away with, their problems would be sorted out. After Ghoghonpur, a boat rally was taken out which ended in a public meeting.

The marchers also came across villages where crop production has become almost nil over the past many years. Harsh conditions have triggered off large scale migration to urban centres, so much so that in many settlements only old people and women have been left behind, who perforce have to depend on moneylenders. Children from these villages are sent as bonded labour to work in the carpet factories of Bhadohi. Still worse, these children are often sold by their guardians.

In several villages along the western Kosi embankment, villagers who have lost their land to waterlogging, still have to pay land revenue. On top of that, they are not entitled to fish in the water that has gathered over their land. Tenders are floated by the government for the acquisition of fishing rights over the water logged areas. These tenders can be filled up by societies of fisherfolk only. However, by floating fictitious societies or else by buying over authentic ones, fishing rights have been appropriated by certain affluent sections, nevertheless, with fisherfolk becoming more conscious of their rights, there is growing opposition to this monopoly of the waterlords.

The Sampurna Kranti Manch seems to be making some headway as they have been able to establish committees in 52 villages along the Kosi embankment and another 34 within the embanked area.

tion through protection works, particularly, embankments. If embankment construction is stopped, the resources, thus, saved could be employed for channel improvements, diversion schemes, and rejuvenation of the natural drainage. The system of *dhars* had brilliantly served the functions of spillage and drainage for years. Since flood plain management has been little studied, the suggested alternatives can at best be extremely tentative but they do seek to delineate an alternative domain of thrust. In any case, the efforts to embank the rivers, control the floods and bring about an assured double cropping system in the flood plains, have failed to increase crop productivity in the area. A recent study of districtwise agricultural performance in India shows that north Bihar districts are not only performing very poorly even by average Indian standards but land productivity also remains almost the same as the early 1960s (see table 51)[147].

A factor that rather acutely compounds the problem in north Bihar is drainage congestion. If growing population, in part, explains this phenomenon, a major part of the blame has to be shouldered by the political leadership of the state. Rather than vigorously implement land reforms and suitably settle the landless on the tracts thus acquired, they have promoted encroachments upon the valley storage potential. More and more chaurs, tals and natural depressions, which had earlier served as natural detention basins, have been brought under agriculture. These factors, in their cumulative, have given the floods a devastating dimension. Drainage decongestion has to be a major thrust in all future schemes. Drainage improvement works have been undertaken by the state government but the enterprise has been miniscule. The human component of the problem will be enormous as it will now involve displacement and resettlement and can be solved only with the vigorous implementation of the land reforms to generate the surplus land needed to rehabilitate the displaced. To reduce drainage congestion caused by the lower catchment precipitation, rain water harvesting can be taken up by constructing an elaborate network of tanks.

A suitable modification of the agronomic practices may also bring down crop damages significantly. Agricultural operations should be rescheduled so as to leave the land free

FLOOD CUSHION: North Bihar abounds with wetlands like this one. Siltation reduces their depth and they come to be known as chaurs which help to cushion floods. But of late drainage congestion has hampered this function and resulted in more waterlogging instead. (Amar Talwar/CSE)

Table 51
Agricultural productivity in north Bihar

Districts	**Period**	**Productivity of 41 crops — value of output (Rs/ha)**	**Gross cropped area (mha)**
Darbhanga,	1962-65	818	0.753
Madhubani and	1970-73	870	0.749
Samastipur	1980-83	857	0.777
Munger,	1962-65	714	1.090
Saharsa and	1970-73	752	1.079
Begusarai	1980-83	846	1.039
Muzaffarpur,	1962-65	710	0.742
Sitamarhi and	1970-73	785	0.779
Vaishali	1980-83	863	0.766
Purnea and	1962-65	787	0.897
Katihar	1970-73	708	0.918
	1980-83	875	0.980

Source : 147.

for flooding during the flood season and take advantage of the soil moisture after the floods or else implement a suitable programme of irrigation for cultivation in the flood free months. Weaning away the farmers from the kharif crop, which has traditionally constituted the major crop of the region, is not going to be an easy task where the bulk of the operational holdings are held by small and marginal farmers and that too in an economic context where the non-farm sector has been virtually stagnant to provide alternative employment opportunities. Implementation of land reforms and organisation of small and marginal farmers into cooperatives may increase their access to institutional resources and augment their agricultural productivity through consolidated holdings. At the same time, in the non-agricultural months, they can profitably engage in rural industry organised along similar lines.

As an alternative to canal irrigation, extensive utilisation of groundwater has been suggested. According to S Dasgupta and N C Ghose, a sample study of groundwater table in all the 13 districts of north Bihar showed the existence of the water table at 4.27m to 6.1 m in general[143]. In fact, certain experts have argued that active development of groundwater reservoirs by extensive irrigation pumping during the dry season can provide substantial capacity to store flood and drainage waters during the wet season[147].

WETLAND STATUS

The flood plains of India are dotted with wetlands all over. Wetlands in India, excluding rivers, artificial impoundments and the area under paddy, cover an area of over 14.3 mha or over four per cent of India's land area. These wetlands perform vital flood control functions, apart from being rich sources of fish, wild birds, irrigation and fodder, and, hence, the livelihood base of many individuals. Nevertheless, a detailed survey of Indian wetlands prepared by James Wolstencroft, S A Hussain and C K Varshney reveals that these water bodies are dying as a result of human intervention and overexploitation[1]. Administrative measures only take short term gains into consideration and think only in terms of land reclamation for agriculture. Increased floods will be the inevitable result. Lakes, ponds, marshes and watercourses in the vast low lying area between the Ghaghara and Ganga form the wetlands of eastern Uttar Pradesh comprising more than 500 freshwater bodies of 100 ha or more and numerous smaller water bodies. The region covers some 2.5 mha, and it is densely populated and intensively cultivated, with the cities of Allahabad, Kanpur and Varanasi on its southern edge.

These depressions and freshwater bodies were previously inundated by overflow from the rivers and local monsoon runoff. Their principal function was to act as sponges and they were nature's own initiative at flood control. However, human intervention has seriously impaired this function by the setting up of embankments, roads and railways which contribute considerably to waterlogging. Reclamation of depressions by filling up *chaurs* for cultivation has compounded this problem. While exact figures regarding the reclamation of wetlands are unavailable, one-third of the area under wetlands, may have been lost.

Largely under private ownership and not subject to any known conservation measures, the use of these wetlands ranges from boating, fishing, water sports, bathing and irrigation to providing fuel for the human populace and fodder for domestic livestock. However, pollution by domestic sewage, overexploitation by humans, drainage for conversion to agricultural land, and infestation by water hyacinth *(Eichhornia crassipes)* have placed immense pressure upon the services the wetlands offer, consequently, modifying both the flow and quality of water.

Many other pressures on wetlands arise as side effects of activities far removed from the water bodies. Fertilisers, pesticides, organic wastes and sediments may be washed down from agricultural lands by surface run off or may percolate into aquifers. Chemical pollutants, oil, heavy metals and other residues may flow into streams, seep into groundwater or be washed down from the roads.

Wetlands are the feeding and breeding grounds for a large range of birds, mammals, amphibians, fish, insects, crustaceans and reptiles. The very diversity of the services that wetlands offer creates problems as one range of activities is rarely compatible with another and exploitation of the wetlands for one use places constraints on their other uses.

The wetlands of the huge region of north Bihar and West Bengal are dependent upon the six major tributaries of the Ganga flowing out from the central Himalaya on to the plains between the Nepalese border and the Ganga itself. From the great Gandak river in the west to the Mahananda in the east, the northern part of the Ganga plain is studded with numerous small freshwater lakes or chaurs, the vast majority of which are oxbow lakes marking the historical courses of the Bayanadi, Burhi Gandak, Kosi and Mahananda rivers[1].

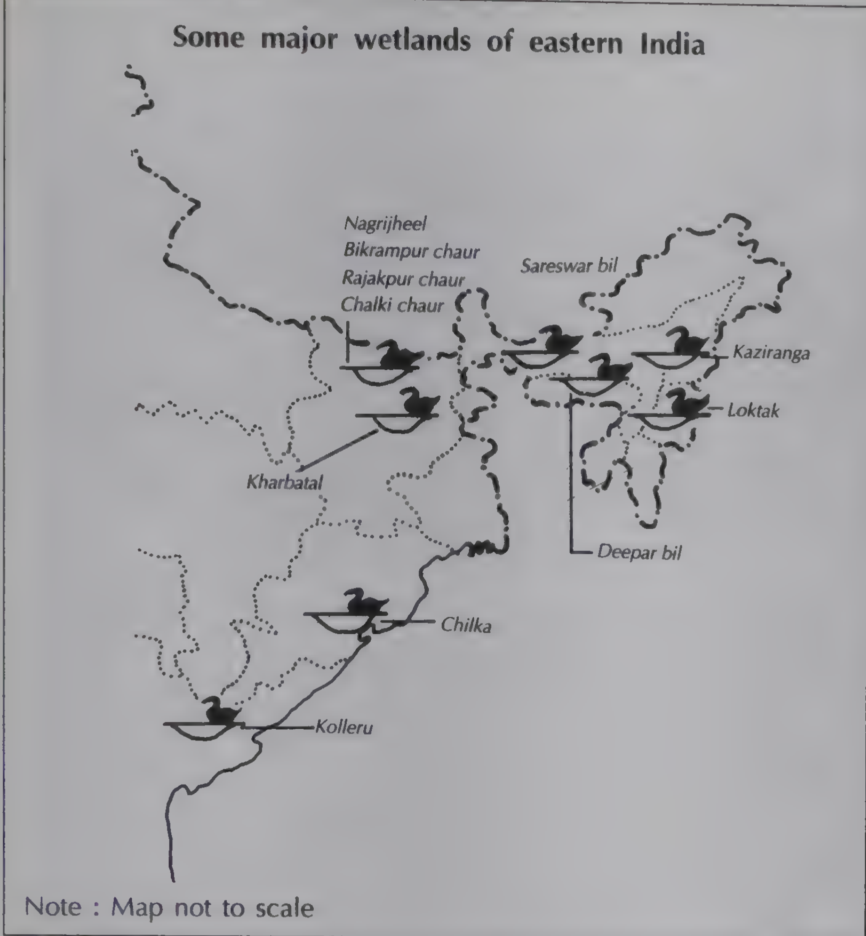
A tropical monsoon climate prevails in the area with an average annual rainfall of about 1,000 mm and temperatures ranging from 5°C-45°C. As the lakes dry out in summer they are covered by creeper grasses. The surrounding area is almost completely under rice cultivation. The region has become the centre of waterfowl netting carried out by *Sahnis*, a group of landless fisherfolk. Ducks, coots and other waterfowl are trapped at night with fine nylon nets. This practice is particularly common in areas around Darbhanga and Purnea. The Saharsa region has Kharbatal, the largest freshwater lake in north Bihar, formed as an oxbow lake by a meander of the Gandak.

The unrestricted spree of shooting and trapping wild birds in the wetlands, alarmed the state wildlife department in Bihar to finally ban shooting in 1982, but trapping of waterfowl still continues on a large scale. Chaurs are particularly abundant southeast of the region around Kharbatal, which is 22 km north

Preliminary calculations made in USA indicate that full development of conjunctive use in the Ganga basin could lead to as much as a 50 per cent reduction in the monsoon flow of the river[147a]. Thus, groundwater utilisation can not only contribute to the full realisation of the agriculture potential of the region but would also be effective in reducing and preventing waterlogging conditions which have come to be an imminent threat in considerable tracts of north Bihar. The measure could considerably alleviate the flood problem of the region through provision of underground storage for monsoon flows. Experts at the Centre for Water Resource Studies in Patna feel that the desired development of groundwater in this area has been inhibited by the preponderance of marginal farmers who cannot afford the investment required in installation of tubewells, lack of effective state initiative, and paucity of electrical power[148].

The prescriptions, as discussed above, offer an attractive enough package for the solution of the problems of this area. Care should also be taken to implement and extend flood proof housing in flood prone areas. The level of disaster preparedness has also time and again left a lot to be desired. Greater devolution of powers at the level of the affected will ensure that the response is fast and intermediaries who try to profit from disaster relief are excluded. This kind of bungling in relief operations in Bihar is commonplace. There is definitely an urgent need to vigorously pursue effective coordination with the Nepal government for a flood forecasting network.

Most of the issues discussed hitherto basically call for a reorientation in perspectives. Policy makers will have to admit to the fact that a major part of the problem stems from a rather misplaced preference for engineering responses in utter disregard of the region's ecological setting. In a situation where almost 85 per cent of those affected by floods belong to the category of marginal or small farmers, there is hardly a choice to be made. The answer to the question why the government persists with its misplaced policy, lies more than anything else, in the politics of flood control and flood relief.



Wetlands play a major role in absorbing the flood waters. Eastern India is dotted by numerous water bodies. Unfortunately all of them are facing a threat to their existence because of human intervention.

of Begusarai and 100 km east of Patna. There are more than 14,000 ha of these wetlands in Darbhanga district alone. Some of the main chaurs in the Kharbatal region are Nagrijheel, Bikrampur chaur, Rajakpur chaur, Chalki chaur and others.

In years of average rainfall, Kharbatal and nearby Nagrijheel and Bikrampur chaur unite to form a lake of about 7,400 ha. By late summer Kharbatal recedes to 300-400 ha exposing 2,630 ha of mudflats which are converted into rice paddies. In 1951 a drainage channel was excavated to expose additional areas for agriculture but the channel silted up in a few years and the lake returned to its original condition. Further siltation has resulted in raising the lakebed.

In 1982 a Bihar state government committee convened to study the problems of Kharbatal stated that the area be declared a sanctuary. Many of the area's natural resources are being overexploited. About 70,000 ducks and coots were sold in the Manjhaul market in 1982. In the winter of 1984-85, the number rose to 135,000. The lake is also very important for its fisheries production in the wet season and supports over 29 species of commercially valuable fish. A large proportion of the inhabitants of the 15 villages around the lake are dependent on it for their livelihood, in particular the 1,300 Sahni families engaged in fishing. There are fears that this high level of exploitation will have a detrimental effect on the lake's resources whose water is now also being contaminated by pesticides and fertilisers[1].

A socioeconomic survey undertaken by the state forest department has concluded that uncontrolled netting of birds in the region should be stopped and rehabilitation of the trappers be carried out by the government. Meanwhile, the drainage division at Manjhaul has proposed that a new drainage scheme be carried out to hasten monsoon runoff and open up another 2,800 ha for rice cultivation. Both schemes are yet to be implemented. So while one arm of the government wants to conserve the wetland, another is keen to destroy it.

Among the other major wetlands of India are the Sareswar *bil* in the Dhubri division of Assam; the Deepar bil, southwest of Guwahati; Loktak lake, 20 km southwest of Imphal in Manipur, a large but shrinking freshwater body; Salt lake swamp in West Bengal, a large area of saline lagoons, ponds and brackish marshes at the head of the Matha waterway on the southeastern periphery of Calcutta; Chilka lake, 150 km southwest of Cuttack; and, Kolleru lake in Andhra Pradesh, 50 km east of Vijaywada.

The Kolleru lake, which plays a major role in cushioning floods in the Godavari valley is connected to the sea by a small waterway called Upputeru. Many of the small and medium streams in the area empty into it. The lake is presently threatened by heavy siltation thereby aggravating the flood problem year after year[2].

Flood politics

The unrealistically multiplying costs of embankment construction and the recurring expenses on their repair have, over the years, given rise to a firmly entrenched combine of politicians, engineers and contractors, each one of whom stands to benefit enormously from the enterprise. While politicians and engineers are paid into cornering of embankment works by the contractors, the latter stand to benefit from the use of substandard material for the work. The consequent breaches regenerate a potential for further income for all the three. Newspapers repeatedly hint at political bigwigs in Bihar who have built their electoral fortunes upon money siphoned off from flood control works. Author and journalist Arvind Narayan Das rather succinctly sums up this state of affairs: "Public works engineering became another flourishing trade. With the construction of roads, dams, embankments and canals after independence, the industry's turnover increased tremendously and all manner of entrepreneurs jumped into it. As much of the construction was of earthen structures in flood prone areas, it was a virtual cornucopia, ever filling up with every monsoon. Where the natural flow of water reduced chances of damage and renewal of public works, strenuous efforts were put in by the public works agencies and contractors to impede it and create waterlogging and flooding. Among such people was the late lamented Lalit Narayan Mishra who, starting as a petty contractor organising *shramdan* (voluntary gift of labour) during the construction of the Kosi embankment, turned making money to play politics and playing politics to make money into a fine art"[149].

Apart from the mercenary incentives from embankment construction inhibiting the political leadership to suitably modify the flood control policy, lure of cheap electoral gains also motivates them to maintain status quo. Embankments, unlike other measures, have a tangible presence and are easier to construct both in terms of time and money. Even their 'apparent' gains have an instant manifestation. Consequently, they serve as an effective electoral ploy for the politicians to woo their vote banks. Naturally, they dig

THE GREAT DIVIDE: This wall built to keep the road safe from floodwaters, but not the village or its people, has been breached by resentful local people. It also symbolises the nature of flood control works in Bihar — divorced from the needs of the people — a source of income for a combine of politicians, engineers and contractors.(Amar Talwar/CSE)

in deeply when they have to defend the given thrust of flood control policy. Last but not the least, they are wilful victims of that developmental ideology which accords productivity precedence over subsistence.

The increasing failure of the flood control works and the mounting damages have made flood relief another lucrative domain for vested operations. Relief expenses are usually more than the investment on flood control work in Bihar. Whereas estimate for flood relief and rehabilitation for the 1987 floods was put at Rs 80.34 crore, the total expenditure on flood control for the year 1986-87 was Rs 47.34 crore[126,133]. The relief and rehabilitation estimates do not include the other costs of restoration which would put the figure at an astronomical Rs 687.53 crore. On the other hand, the total investment on flood control works since the commencement of the First plan till date has been about Rs 374 crore. Flood relief work has become just another channel by which those in power bestow favors on local interests aligned to them. Relief operations provide ample scope for politicians, officials and contractors to indulge in blackmarketing, diversion of funds, distribution of substandard material and, thus, enriching themselves. This is common knowledge as far as the local people are concerned.

This entwining of political interests with flood control and relief measures is a telling commentary on the extent to which the politics of power can degenerate, where political capital is sought to be made out of even human misery. Little wonder then that the state government has displayed clear evidence of the lack of a political will to proceed alternatively with flood control measures.

It is, however, not true that the affected in the flood ravaged area have been unwitting and mute observers to this charade of development being played on them. Given the locational disadvantage that the bulk of the affected suffer from, their protest often goes unregistered in quarters that matter. There has been little effort on the part of the intelligentsia to translate this concern into sustained people's agitation or else exploit its advantages as a pressure group to modify political programmes and enforce administrative action. Nonetheless, people, time and again, on their own initiative, have chosen to register their protest against the government's policy drives. According to Raghupati of Sampurna Kranti Manch, a group of grassroots political workers," way back in the mid-1950s, when the embankments were in the first phase of their construction, there were a couple of occasions when people rose in organised protest against their construction and there were even instances of police firing against them. Again, in 1978, following a constant struggle by the local peasantry,

WHAT A WASTE: Rich farmlands get converted into marshy wastelands in Bihar as waterlogging takes place on both sides of an embankment. If embankment construction was stopped the money thus saved could be employed for channel improvements, diversion schemes and rejuvenation of the natural drainage. (Amar Talwar/CSE)

authorities had to suspend work on the Gandak Canal Project." Apart from these stirrings of protest, there have been political activists who have been consistently trying to highlight the ills that have ensued from the flood control works and are organising local consciousness against these measures.

Meanwhile, Bihar continues to languish under the recurring impact of floods. While the scale of damage might vary from year to year, it has displayed a consistent pattern. Apart from direct damages, the floods have caused massive disruption in the lives and economy of the affected region with ripple effects, not just in the flooded areas and not confined to the actual periods of inundation.

Waterlogging has not only left valuable agricultural land unfit for cultivation but also substantially reduced the productivity of cultivable land. In some parts of Saharsa district, the problem of surface drainage congestion has become so acute that even for their daily ablutions, people have to use boats and survive on roots and snails. Unfortunately, governmental actions do not show any appreciation of these human dimensions of the flood problem. Perhaps, this excerpt from an editorial in *The Times of India* best sums up the current situation, "A state bountifully endowed by nature has been turned into a land of disasters by unthinking development, disregard of social ecology and unbridled corruption. By its own alchemy of technological arrogance, ineptitude and plain corruption, the state in Bihar has converted the temples of modern India into sacrificial edifices. And when nature takes its revenge, the state abdicates its responsibility"[150].

- *Himalayan rivers bring down vast quantities of silt and have wide river beds. Known as khadar or diara, these areas make up land — in Assam, Bihar and Uttar Pradesh — equivalent to one per cent of India's area.*

- *In poor and densely populated India, even these annually inundated flood plains are occupied by humans. As monsoon flows recede, large patches become available for cultivation and grazing cattle.*

- *As rivers keep eroding and shifting the government must survey and reallocate diara land regularly to those whose fields have been washed away by the river. But few areas have been surveyed.*

- *Thousands of poor people have been dispossessed through official connivance and over three-fourths of the diara in Bihar is illegally sharecropped.*

- *Caste wars, gangsterism and mass murders are common in the Bihar diara, making it possibly the most violent area in India. The first massacre took place in Bhagalpur district in 1955, Abhaiya in 1980, Piparia in 1984 and Taufir in 1985, followed suit.*

- *Instead of sorting out land ownership issues the state supports the landlords and their gangsters. Middle class residents of Bhagalpur supported the wilful blindings of petty criminals by the police in 1980 because of their antipathy to diara gangsters.*

- *Environmental changes — growing river pollution and drainage congestion and prolonged waterlogging because of embankments — are adversely affecting crop production and now threaten the very survival of diara farmers.*

Crisis in the Diara

In poor and densely populated India, human beings occupy every inch of ecological space within the physical environment for subsistence and survival. The Himalayan rivers, which bring enormous quantities of silt, cover vast expanses of land as their beds. When flood waters recede, large tracts become available for cultivation. These active river beds — known as *khadar* in western Uttar Pradesh and *diara* in eastern Uttar Pradesh and Bihar — are today the habitat of millions.

The diara and khadar areas suffer floods and erosion every year. Even as the river erodes one area, it can build up soil in another area. And changing course suddenly during a high flood, it can submerge vast tracts along one bank while opening up large new areas on the other. As a result living conditions in diara areas are extremely amorphous and unpredictable.

The inhabitants have to continuously struggle against the vagaries of nature. Living on the fringe of civilisation leaves them destitute. The social and the caste networks are such that they breed a lot of criminal activity. Land usurpation is common in an area devoid of any systematic administration, where the rule of misrule, is the standard practice and not the exception.

Using the main stream of the river as a reference, diara and khadar lands can be divided into three categories. Firstly, there are the main river bed diara lands which lie inside the river bed. These get flooded every year and are available for cultivation only during the summer months, that is, about five or six months from December or January to June. Secondly there is the slightly elevated mid region,

CHANGING PANORAMA: The diara areas suffer floods and erosion every year. Even as the river erodes one area it can build up soil in another area and changing course can suddenly submerge vast areas. The picture shows silt deposition building up land in the Ganga in Bihar.(Amar Talwar/CSE)

located on the banks in varying widths known as mainland diara land which is frequently inundated during the flood season. But as it is submerged for a maximum of three months, it is available for cultivation eight or nine months a year. Thirdly there are the upland diara lands, lying above the mainland diara lands, which have got a higher elevation because of alluvial deposits in the past. These are even less frequently flooded. They may get flooded for a month or two during August or September during a year of heavy floods but otherwise can be cultivated over the year if irrigation facilities are available[5].

In eastern Uttar Pradesh, river plains were traditionally divided into diara and transdiara lands, also known as *bhangar* lands. While the latter would be traditionally cultivated twice a year, the diara lands could be cultivated only once a year for the rabi crop[151]. The villagers in Bihar identify two types of diara. Firstly that which gets flooded once or several times in a decade and secondly the *karar* diara, which floods once in several decades or even once in a hundred years.

Each time land is flooded, large scale displacement of people results. The annual floods only cause temporary displacement for three or four months. But when the river changes its course, no one can tell when the submerged land will emerge again. The diara inhabitants, as a consequence, have to wander for years in search of a place to settle.

Extent of the diara

Diara and khadar occupy vast areas in Assam, Uttar Pradesh and Bihar. Where a river meanders or braids, diara can cover a large width of land ranging up to 12 km but where it flows in a straight section along a deep river bed, the diara land will lie in thin strips along its banks. Taking an average width of about eight km per km length of the river, the diara land along different rivers of Uttar Pradesh is estimated to be 1.54 mha. Most of it is in Ballia, Ghazipur, Allahabad, Farukhabad and Etah districts (see table 52). This area is spread along the Ganga, Yamuna, Ghaghara, Sarda, Ramganga, Gomti and Kalinadi rivers (see table 53). In Bihar, the Ganga diara alone extends over 200-250 km. Nearly 0.9 mha diara land can be found along the Ganga, Gandak, Burhi Gandak, Son and Kosi (see table 54)[5]. Assam has another 0.24 mha of diara lands. Thus, Assam, Bihar and Uttar Pradesh alone have about 2.64 mha of diara lands[152].

Table 52

Diara land in select districts of Uttar Pradesh

Districts	Diara area Actual (mha)	Diara area % of district's area (%)
Meerut	0.02	4
Etah	0.10	24
Farukhabad	0.14	24
Kanpur	0.06	9
Allahabad	0.12	17
Mirzapur	0.02	-
Varanasi	0.01	3
Ghazipur	0.07	21
Ballia	0.17	31
Total	0.71	

Source : 5

Table 53

Diara land along different rivers of Uttar Pradesh

Rivers	Diara area (mha)
Ganga	0.41
Yamuna	0.4
Ghaghara	0.16
Sarda	0.072
Ramganga	0.17
Gomti	0.2
Kalinadi	0.13
Total	1.54

Source : 5

Table 54

Diara area in Bihar

Rivers	Diara area (mha)
Ganga	0.24
Gandak	0.14
Burhi Gandak	0.23
Son	0.11
Kosi	0.15
Total	0.86

Source : 5

SURVIVAL IN THE DIARA

The mood of the river dictates diara lifestyles. Consequently diara villages have no pattern, form or fixed boundary. Heavy damages to crops, property, lives and cattle are frequent. The inhabitants know they will be displaced sooner or later. Villagers displaced by annual floods take shelter in nearby towns, on railway platforms, bus stands, pavements and along roadsides. Like animals, they forage for food and shelter receiving reprimands everywhere. Bhagalpur, Munger, Kahalgaon and Sahebganj on the main road along the southern bank of the Ganga witness a sudden influx of people. Even a casual observer can see hundreds of people huddled in small plastic tents along the highway and on roads. Town folk resent their presence since a lot of criminal activity has come to be associated with the diara people. They get little work in the towns and their rations get exhausted quickly. They are thus forced to work for very low wages with men often pulling rickshaws and women

BARE TRUTH : The well, which was originally in the centre of Chakk Gaon, is now on the bank of the river and powerful currents have left it naked and exposed. (Amar Talwar/CSE)

GANGA'S DANCE

In Kaithi village, situated at the confluence of Ganga and Gomti, farming is carried on with the help of the police. Some time ago about 900 ha of fields were submerged by a sudden change in the Gomti's course but new land had emerged, resulting in prolonged tension and violent clashes between Kaithi and neighbouring Patna village. The judicial verdict was in favour of Kaithi. But the state's Provincial Armed Constabulary (PAC) has had to be stationed there, making Kaithi possibly the first village in India where farming is done under police protection, according to Chandi Prasad Bhatt, one of the leaders of the famous Chipko movement[1].

Village after village along the Ganga is suffering from floods and heavy erosion, state members of the Dasholi Gram Swarajya Mandal, the Gopeshwar based voluntary organisation which pioneered the Chipko movement. The Mandal workers undertook a *padyatra* in 1987 along the middle reaches of the Ganga to create awareness of environmental conservation and afforestation amongst the local villagers. These marchers held 40-odd meetings in villages, schools and colleges of Varanasi, Ghazipur and Ballia districts of Uttar Pradesh and Saran and Patna districts of Bihar.

Chandi Prasad Bhatt says the workers found that in the Sarai Mahana village of Varanasi district, situated at the confluence of Ganga and Varuna, erosion had already destroyed many houses.

Near Sugapur, Ghazipur district, the Ganga takes a sharp turn. Erosion and changes in stream courses are acute. The *padyatri's* found that Sugapur villagers are willing to afforest 40 ha of their village land if they can get government help. The villagers claim that if erosion by the Ganga is not checked, a sudden change in its course would affect about 100 villages inhabited by about 80,000 people. In the south, near Nooranpur, a small village has already been submerged. Bans Ropan Singh, a local villager, has lost 3.5 ha out of his 3.7 ha of land. "I wish we could all die than to live a life of misery," he told Chandi Prasad Bhatt. Every year, erosion transforms landowners into landless beggars. "At Sherpur college, we were told that the office room we were sitting in comes under knee deep water," says Bhatt. "Furniture floats in the water like boats. All activities come to a halt." During high floods, people stay on trees, even defecating from there. The greatest problem during floods is fodder scarcity, resulting in a heavy toll of cattle. The local people confirm the existence of dense forests along the banks of the Ganga at one time. But today, with the exception of a few places, there are no trees left.

Shiv Govind Upadhyay of Sherpur claimed that a few years ago, forests covered about 800 ha along the banks of the Ganga. Consequently, cattle and milk were in abundance. But now the forests have largely gone. A local villager, Janardan Rai, had planted 0.13 million trees like mango, jackfruit, *sheesham* and *jamun*, 20 years ago. Of these, only a few thousand are still growing.

Ganga was six km away from Sherpur. Now it is only 1.5 km away. Every year, the villagers make temporary check dams. Constant vigil is kept over them during floods. Every house in Sherpur has a series of check dams. The first is in the open space before the house, the second is at the doorstep, the third inside the rooms, and finally, there is a raised platform.

The villages of Garha Pargana in Ghazipur and Ballia districts are the worst affected. The distance between Tons and Ganga has reduced considerably. Basthan village, earlier located at the confluence of the Ganga and the Tons, has moved up the road. Most villagers of Gareeb Tola in district Saran of Bihar are now staying at Revelganj. Flood affected migrants are settling all along the road uptil Chhapra.

Erosion at Malkha Chak has swallowed about 20 houses. The historic Gandhi Kutir stands on the river's edge facing extinction. Villagers of Surahi and Visartpur in district Ballia complain that Bihar government has constructed an embankment on the Bihar side and flood waters now spread on the banks in Uttar Pradesh, speeding up erosion there.

Pollution is also a serious problem now. Varuna at Varanasi presents a distasteful sight. People wash their clothes on its *ghats*. Patches of detergent foam can be seen floating all over. In Ghazipur district, the stink from the distilleries at Nandganj is oppressive. The Gangi carries all the factory wastes from Nandganj to the Ganga. Ghazipur town adds more drains to contaminate the river. The effluents of the sugar and opium factories at Ghazipur compound the problem.

At Gaighat, local fisherfolk said they earlier had traditional rights to fish but now the bigwigs capture the fishing contracts, and half of their daily income is pocketed by them. Fish has also declined sharply. The new nets are catching even the smallest fish, the number of fisherfolk has increased and the Farakka barrage downstream prevents the fish from swimming up the river.

working as housemaids.

The plight of those permanently displaced due to erosion is all the more pitiable. Populations of entire villages get displaced and are rarely resettled in the old way. Journalist Mukul Sharma in *Navbharat Times* describes the case of hundreds of displaced families from Shankarpur diara near Bhagalpur. The local administration was not prepared to settle them within the precincts of the town. From 1971 to 1985 they kept wandering. In 1986, some 300 families were settled by the government far away from the town on about 1.3 ha of land. Bungling in land distribution worsened the already dismal scenario of settling so many families on so little land. More than half the people did not get papers for their land. Many families had to get land through graft while in some cases, members of the same family got separate allotments.

The diara areas have remained backward and neglected without facilities like water, electricity, roads, health centres or schools. The unpredictability of their environment makes investments in these areas impossible. Various problems stem from this kind of marginal existence. Epidemics are rampant amongst cattle and human beings in the aftermath of floods and consequent displacement. The diara is also surprisingly prone to droughts, despite the river being so close. There is a shortage of drinking water and irrigation facilities.

The diara have thus come to represent the worst living conditions. Despair and disease have made heavy inroads into the average inhabitant's life. Because of their semi-nomadic existence and extreme poverty, there is no scope for education or learning. Childhood is lost in family tensions, aimless struggles and constant wandering. Shep-

VANISHING HOMES: Villagers of Chakk Gaon breaking their houses to save the material from the Ganga which threatens to erode them. Over half the village has already succumbed to erosion. (Amar Talwar/CSE)

herding and ploughing thus assume more importance than schools.

Moneylending is common and a lot of diara land has fallen into the hands of moneylenders, who hoodwink the farmers. The latter lose their land and become sharecroppers. The diara people need loans for sowing in October. From time to time they need loans for litigation, which increases their debt. The diara farmer thus subsists on the verge of penury with the moneylender often picking up half his crop in addition to his services as a sharecropper.

Because land rights are not properly defined, land grabbing, caste conflicts and massacres are common especially in Bihar. Each year during the rains, the river spreads several kilometres wide covering agricultural land. When it recedes, the land gets unevenly distributed, especially when the main current of the river changes course. In the absence of any survey, the powerful sections forcibly grab and control the land. In this process, the actual owners are reduced to sharecroppers. A struggle against exploitation and tyranny has become part and parcel of life in the diara.

Agriculture

Almost every year, the land gets submerged thus getting new layers of soil and sand. The Ganga diara soils are alluvial with moderate fertility. A thick layer of sand can be found on diara lands close to the river but the layer becomes thinner further away from the river current. Lands with a

TRADING PLACES : Building material being piled on a road at a higher elevation by villagers who have abandoned their village. (Amar Talwar/ CSE)

thick layer of sand are not good for cultivation. The rest are, however, very fertile because of the soil deposits left behind by the waters. The land which emerges for the first time, after a river has changed course, is usually not cultivable right away. It takes three or four years before it gets ready for cultivation. Two kinds of wild grasses — *Jhaua* and *Kash* — start growing on this land. They play an important role in holding the soil together. With their roots going deep down making the land strong for cultivation.

Two main crops are usually grown in the diara — the rainy season kharif crop and the winter rabi crop. The latter usually more successfully because the kharif crop generally gets destroyed by floods in four out of five years. In a year of heavy floods, the rabi crop can also get delayed, especially if flood waters linger. The area is also vulnerable to drought. In Bihar, irrigation is available on only three per cent of the land. In a drought year, therefore, the rabi crop also perishes. While the time of sowing is important in all forms of agriculture, it is vital in the diara. If the summer maize is sown too early, it will begin to flower even when hot westerly winds are blowing. If the sowing is delayed, the crop may be lost to floods.

However, floods deposit fertile silt in low lying areas during the monsoon season and the winter rabi crop is grown on this rich soil. A good rabi crop makes up for the partial and uncertain cultivation in *kharif*. In eastern Uttar Pradesh it is not uncommon for the bigger farmers and landlords, who produce for profit, to leave the land uncultivated during the rainy season and in this way reduce losses and maximise profits. But small farmers, who cultivate largely for subsistence, try to take two crops. Floods, therefore, have a greater effect on them.

Cropping patterns vary. Near urban areas, cucurbits, that is, melons, pumpkins, bottlegourds and summer vegetables are intensively grown. In the mainland and upland diara, mostly cereals, or a combination of cereals and pulses or oilseeds are raised. The diara farmers east of Allahabad are extensively used to raise a combination of wheat and rapeseed or mustard, or of barley and rapeseed or mustard during the rabi season. The diara farmers around Kanpur raise two crops of brinjal for profit. Kharif maize is an important crop grown over 0.6 mha of diara lands in Bihar. Between the standing rabi crops of wheat or barley in upland diara, peasants will sow seeds of cucurbits and summer vegetables in well manured small holes just before the harvest of the cereal crop. The young plants establish well and supply summer vegetables.

The need for irrigation water to intensify cultivation remains. Farmers have taken to shallow tubewells and low lift pumping from the river. Bamboo tubewells have been popular in the Kosi diara. In Ghazipur district, some landowners have resorted to pumping water directly from the river with the help of electricity or diesel powered pumpsets placed on floating barges.

The RBA set forth a general cropping strategy for the diara lands in 1980. The suggested strategy includes intensive rabi cultivation after the flood waters recede, postrabi summer cropping till the rains, and kharif cropping mostly with paddy varieties which can withstand long periods of waterlogging and submergence of at least up to a week. To intensify rabi cropping, the commission strongly advised the government to provide irrigation facilities.

Unfortunately, little attention has been paid to diara agriculture by research scientists. A recent workshop held at the Centre for Regional Studies at Bhagalpur university pointed out that "a cropping and plantation system suited to its distinctness can yield better harvest and gainful living for the diara dwellers. The fertility of the diara soils has not been scientifically utilised by evolving a conducive cropping system." The workshop noted that agricultural scientists must be motivated to investigate the problem[152]. However, according to the Indian Council of Agricultural Research, numerous new varieties and other agricultural technologies and practices have already been developed. For instance, plantation of trees which provide fodder, fuel and green manure can greatly help to improve soil fertility.

But there are numerous social and other problems in promoting technology transfer to the diara villages. Firstly

MEAGRE INCOMES: Daihars, diara villagers involved in the milk trade and animal care, take their meagre produce for sale to town. Middlemen ruthlessly exploit these daihars. (Amar Talwar/CSE)

over 80 per cent of the people are marginal or landless farmers. They have very little resources to invest and get satisfied with whatever they can grow even if their land slowly loses its fertility. Secondly, extension workers find it very difficult to work in the diara areas. There is no coordination between different agencies of the government[153]. Thirdly transport and marketing facilities are inadequate. Farmers depend on boats and ferries to sell their produce. They go early in the morning to town to sell their produce and return late in the evening, thus depending entirely on the whims of the traders to get a proper price. The crisis ravaged diara dwellers can ill afford the existing system of marketing and need an alternative urgently[152].

Animal care

Another means of livelihood is cattle rearing. Cow and buffalo milk is sold on a large scale by the peasants in nearby towns. There is no dearth of pastures in the diara . In fact, the diara are considered ideal for dairy activity. The area is known for its cattle wealth which has been the mainstay of the livelihood of the *Gwalas* (cattle herders). Well known breeds of *Ganga Tiri* and *Shahabadi* are considered efficient milk producers in Varanasi, Ghazipur, Ballia and Shahabad. *Murrah* buffaloes are popular in the diara[5].

However, the flood period poses serious problems when large herds have to be shifted to the mainland for safety and grazing. There is an acute fodder scarcity during this period as diara pastures remain under water and the fodder sold in the towns is very dear. After the floods, however a luxuriant grass growth covers the lands but floods also bring with them diseases which lead to a heavy toll amongst the cattle. There is no provision for the treatment of ailing cattle. Flood months weigh heavy on the poor farmers who have to sell their cattle in order to survive. This is the time when the diara people are unable to manage even one square meal a day.

Middlemen in the milk trade also exploit the *Daihars* (as the diara milksellers are known in Bihar) to the hilt. Poverty forces them to sell most of their milk keeping very little for themselves. The rich landlords and the milk traders make huge profits while the peasants and the daihars only manage to eke out an existence.

Fisheries

Fishing is a major occupation in the diara and Munger area fish is sent up to Patna and Mughalsarai. The Bhagalpur diara fish is sent to Bhagalpur and Patna. The Kahalgaon, Kursela and Katihar diara fish is sold in Siliguri. The north Indian region of the Ganga is very rich in fish. The trade peaks from May to September. Large areas in the diara get waterlogged and several small currents survive away from the river forming large ponds at some places which become sources of large amounts of fish.

Nearly 40,000 fisherfolk live in about 50 to 60 hamlets, with some 100 families each in the Ganga diara of Bhagalpur district. There are another 15,000 in the Kahalgaon diara. Many also come from outside, fishing being the only livelihood of these people.

However, a constant control is exercised upon them by the waterlords and their contractors. Even after abolition of *zamindari* (landlordism) in 1954, waterlordism continued until recently from Sultanganj to Peripainti — a stretch of about 80 km — in Bhagalpur district. A water tax was levied in the name of Gods. In legal terms, the monopolist had the status of merely a servant of God. The government made no new law to end the private water tax. Years ago, a case was filed by the government against this. The lower court of Bhagalpur had decided in favour of the fisherfolk. But in 1964, in an appeal filed by the waterlords, the Patna High Court gave a judgment in favour of the latter. The High Court gave two arguments in this context. Firstly, water tax monopoly was given by a Mughal emperor and it was continuing from generation to generation. Secondly, water rights are different from land rights and they come under that form of property which, unlike land, is movable. For this reason, waterlordism is not covered by the Land Reforms Act. The Bihar government appealed in the Supreme Court,

UNIQUE WATERLORDISM: Children of fisherfolk raise their voices to protest against the hated water tax of the gangsters and waterlords.(Krishna Murari Kishan)

after eight long years, that is, in 1972. Because of the government's laxity and the doubtful nature of the appeal, it was dismissed.

This water tax monopoly of Mughal vintage was unique not only in Bihar but in the country. For fishing in the Ganga the fisherfolk had to take a yearly lease for which they had to pay an average of Rs 700. Rates varied for different kinds of fishing nets and boats. The fisherfolk had to pay extra for rights to fish during the rainy season.

In the rainy season, the waterlords would take up the business of catching fish fingerlings in the Ganga. While these people earned lakhs from this business, it had the effect of a curse on the fisherfolk reducing the quantity of fish in the Ganga. As a result, the fisherfolk often caught very little fish even after hard work and night long vigils.

There is a lot of violence, murder and litigation in the fishing business. Every year after the floods or due to the river changing course, some land invariably gets waterlogged. This area is called *margang*. These water bodies, which are rich in fish, dry up after some years, or at times, even in one year. The original owner then resumes farming on the land. But in the diara the owner of the land has no fishing right on the margang or the ponds. He not only loses his land to water but also gets no right to catch fish in his own water filled land. Powerful landlords and criminal gangs control the fishing in the margang and temporary ponds. Even the Bihar government laws do not recognise the right of the landowner on the margang. The Bihar government legally owns the margangs but there is very little legal management on its part. Every year many lives are thus lost in the fights to control the margangs which are forcibly occupied and the farmer owning the land cannot even come close to it. Margangs are referred to as mines of fish and the landlords and criminal gangs controlling them make lakhs. There are several kilometre long margangs which have been under illegal occupation of landlords for years.

Even after taking out a fishing lease from the waterlords, the villagers' agony would not end as they would have to pay a regular tax to the criminal gangs apart from this, otherwise their fish would be looted.

The business of selling the diara fish has become an organised industry with most fisherfolk confining themselves to catching fish, the market being controlled by powerful traders who pressurise the poor fisherfolk. Cooperatives set up to ensure fair returns to them are in a sorry state. Their function is limited to election of office bearers and appropriation of government funds. The cooperatives are under the sway of the traders and landlords and are often used to exploit the fisherfolk in an organised manner.

As a result, a large section of fisherfolk has shifted to professions ranging from rickshaw pulling to manual labour. In Kagazi Tola of Kahalgaon, the biggest fishing hamlet, there are merely 35-40 boats left whereas, at one time, the area had about 100 boats devoted to fishing.

DIARA VIOLENCE

Today in India the diara — especially in Bihar, — has become a region of extreme violence, probably the worst.

The social set up is a composite consequence of interwoven links of caste, class, occupation, power and money where backward castes constitute a majority. The *Gangotas, Mallahas* (fisherfolk), *Dhanuks*, Gwalas (milk sellers/herders) *Khairwars, Tantis, Koeris, Kurmis, Yadavas, Bhumihars* and *Rajputs* inhabit the diara. The Gangotas, Dhanuks, Koeris, Kurmis and Yadavas belong to the backward castes and the Rajputs and Bhumihars to the upper castes.

In his 1891 study on *The Tribes and Castes of Bengal*, H H Risale described the Gangotas as the cultivating, land owning and farm labour caste of Bihar living on the banks of the Ganga, from which their name originates. The Mallahas are the boating and fishing castes found living in association with rivers across Uttar Pradesh, Bihar and Bengal. According to Risale, Gangotas and Mallahas seem to have been the original inhabitants of the diara. But the Yadavas, Gwalas and Bhumihars who probably arrived later in search of new pastures and cultivable lands have played a major role in changing the socioeconomic structure of the area.

They introduced new dynamics by giving rise to conflicting interests between the original inhabitants and the new settlers. It seems that the diara areas were once largely used as a common property resource — as a pasture land — and as loosely demarcated private croplands. These rich pastures must have attracted communities of cow herders like the Yadavas. As the population grew, more lands turned into croplands and the area slowly began to be used more as a private property resource. While backward castes like Yadavas, Kurmis and Koeris were able to get more lands than the Gangotas, they themselves together with the Gangotas, worked at the mercy of powerful upper caste Rajputs and Bhumihar landlords. At the time of independence, the diara were the property of powerful landlords.

In 1923, the revenue department had undertaken a survey of the Kosi diara in Purnea. The final report published in 1926 claims that, during the survey, powerful people of the area ensured that they got a legal stamp over their seizures. The survey officer remarked, "After a tour of the area it is difficult for any officer to believe that the poor have merely some dismal residential land in some corner of the village and the entire agricultural land belongs to people of some different district."

Between 1901 and 1911, the Kosi current moved westward thus leaving large areas flood and erosion free, laying bare a lot of new agricultural land. A survey of 40 villages which was carried out from 1923 to 1926, since land boundaries had been wiped out, revealed that the stronger tenants had increased their land at the cost of their weaker neighbours. This land was tilled by *Santhals* and *Gangols* on a sharecropping basis who were removed after three to four years. Apart from this, people from Chapra and Muzaffarpur came and occupied this new land. They were given land rights by the Darbhanga Maharaja and paid him rent getting their tilling done by farmers who came from Munger, Bhagalpur and Santhal Parganas.

It became clear from this pilot survey that the newly emerged land from the Kosi was going into the hands of managers and cosharers of the Darbhanga Raja and the

actual land tillers were left insecure. In 1922, the district collector had admitted that the area was teeming with land disputes and consequent criminal activities necessitating a comprehensive survey of the area in particular of that under the Darbhanga Raja.

But even then violence was limited. Though the land was owned by big, upper caste landlords, farming was still being done by the lower castes. The seeds of murder and violence were, however, sown soon after independence[154]. The maximum benefits of the Zamindari Abolition Act of the 1950s went to backward castes like Kurmis and Yadavas. The landlords began to throw the poor out of their land and, in some cases even chase them out of the diara to appropriate their lands. The poor could not resist the powerful landlords and the Bhumihar, Yadava, Brahmin, Rajput, Kueri and Kurmi landlords gained in strength.

Around 1955, the first massacre took place. A large tract of land which had emerged in the Shankarpur diara area of Bhagalpur district was the bone of contention. The musclemen of the landlords were sent in to gain control over the land, killing numerous people in the bargain. This incident broke the confidence of the poor.

Because of the recurring erosion and submergence of land, proper surveys have never been carried out. This is an incentive to the powerful to grab land at every opportunity. The surveys and settlement of Bhagalpur district done from 1902 to 1910 under the leadership of P W Murphy, ICS, did not include the diara.

There was a special Ganga diara area survey between 1908 to 1915 but its aim was only to fix the boundary of the diara area. According to this report, the survey settlement of the Ganga diara was done between 1862 to 1865 but no details are available. In 1950, the survey settlement of Bhagalpur district was started but the Ganga diara was again ignored. Between 1950 to 1955, the land disputes of the Bhagalpur diara became extremely violent.

In 1958, the Bihar government ordered survey settlement of the Ganga diara of Bhagalpur. Started in 1959, it lasted till March 1965. During the survey, the first in the area, a large number of farmers and sharecroppers were dispossessed as there was large scale bungling. Inspite of that, in many areas, due to the influence of *kisan sabhas* and other farmers' organisations, records were made and maps prepared in favour of the tillers. The illegal occupation by big landlords and landowners came to light. But even as the survey settlement was completed, the Bihar government suddenly suspended it declaring that it had no "permanent authoritative significance." No official explanation was forthcoming nor a fresh survey ordered.

Thus, the entire diara of Bhagalpur district remains unsurveyed for the last 100 years. Despite zamindari abolition and other land reforms, there has been no legal management of the land. The same is the plight of diara areas in the districts of Munger, Sahebganj and Katihar. Bihar government's *Estate Manual* 1953 provides for annual survey of the diara and instructions have been provided for implementation. The land thrown up by the Ganga will first belong to the tenant whose land it was before it went underwater, and if there is no previous owner, the land will vest with the government. But in the absence of a permanent survey settlement, this is meaningless. Even in the diara area where survey settlement was undertaken, no implementation has been done for the last 10-15 years. In 1950, survey and settlement of the Kosi diara was begun again. The aim was to establish the right of the tillers on their land. This, however, was faulty to begin with being based on the preindependence 1923 survey settlement because of which there was no improvement in land records in favour of poor farmers and sharecroppers. The new survey settlement, based on an earlier faulty survey, further dispossessed the poor, landless and sharecroppers. The survey, which aimed at ending land disputes and tensions became the cause of new land disputes. After 1950, there has been no more survey settlement or amendments in the Kosi diara.

Though it is true that no land survey can be perfect in providing solutions, government agencies have definitely ignored the special problems prevailing in the diara. While the government does not collect revenue for submerged diara lands, it does levy a cess even on lands submerged and not cultivable for years. No detailed legal study has been carried out to suggest suitable land reform measures for the diara lands[152].

As a result of this governmental bungling, violence has kept on increasing in the area. Poverty, disease, unemployment and indebtedness have reached unbelievable proportions and diara inhabitants have lost almost all their lands. Land surveys and reforms have not only failed to protect them but have succeeded in making land disputes more coplicated and violent. Simultaneously, diara politics has got deeply enmeshed with caste networks and criminal elements. During the 1950s, there were several leftist groups which led movements and protests on the question of land distribution in the diara areas. But the diara area and neighbouring towns remained relatively free of criminal activities.

In 1967, the Naxalite movement, which gained a hold in the diara, once again spoke up for the poor in the area. But because political parties have stayed away from the

Table 55

Land use in diara villages

Village	**Total area (ha)**	**Net sown area (ha)**	**Area sown more than once (ha)**	**Area irrigated (ha)**
Ganga diara, Ghazipur district (UP)				
Average for	621.62	449.78	127.1	59.12
30 villages		(72%)	(28%)	(13%)
Ganga diara, Bhagalpur district (Bihar)				
Average for	493.5	354.3	198.7	25
4 villages		(72%)	(56%)	(7%)
Brahmaputra diara, Lakhimpur district (Assam)				
Average for	426.4	286.71	105.85	NA
14 villages		(67%)	(25%)	

Source : 159

ENDANGERED VILLAGE

The Kahalgaon area of Bhagalpur district has a very big *diara.* It has been badly affected by the change in Ganga's course in 1987, says Mukul Sharma in a report in the *Navbharat Times.* Taufir village out here is in a most precarious state. Before the 1987 floods, the Ganga was about four km away from Taufir but now it is merely half a km off. Some of the outer and residential areas of the village have already been lost to the Ganga.

Taufir is a village of nearly 200 houses with no roads or vehicles, there is a single path through the fields which is uneven and full of water and slush. Krishan Das has been living in Taufir since his grandfather's time. According to him, "the village has seen many ups and downs but the latest erosion threat has left all helpless." Middle aged Harihar says it is difficult to live under this suspense; "We are prepared to settle anywhere to save our lives but nobody is prepared to let us settle." Men and women, young and old, all are acutely aware of the erosion threat. The village school has closed down, daily life has shrunk to a few activities, but few are able to find a way of escape.

According to the villagers, a similar threat had loomed over some prosperous diara villages of Sultanganj and Munger. The villagers were influential. The government immediately placed huge boulders to form a bund and the current slowly changed its course.

The administration has been repeatedly requested to adopt the same strategy in Taufir. But to no avail. There is land available in neighbouring Nandgola village. The Taufir villagers decided that they would take over about 0.5 ha of land belonging to absentee landlords and make their houses there. The local sharecroppers had no objection to this. The villagers started making their huts.

The local administration, however, intervened on a complaint by the landlords. The huts were ordered to be demolished, some people arrested and cases filed against others. The huts could not be demolished because of stiff resistance by the villagers but further settlement work came to a halt and policemen were posted on the land.

Taufir's villagers lack the ability to purchase alternative land. Before 1971 they had nearly 200 ha of agricultural land. By now over 160-175 ha have gone under water. The only source of livelihood for the villagers is agriculture and with their farmlands gone, they have nothing left. The remaining land can also be devoured by the Ganga any day.

AFTER THE MASSACRE: A strong police presence in Taufir is an ephemeral matter. Once the uniformed men departed, the area will again simmer with caste tensions. (Krishna Murari Kishan)

DIARA FARMS

Shankarpur *diara* lies to the south of Bhagalpur town. Covering several villages with a total of about 650 families, it gives us a good indication of the exploitative and unproductive state of agriculture in the diara, which continues only because alternative means of livelihood are scarce says Mukul Sharma in a report in the *Navbharat Times*[1].

Only 15 per cent land of the diara here is cultivable, the rest is covered with water or sand. Wheat, barley and gram are sown in October and harvested in March. Peas are sown in September and harvested in February. *Kalai* is sown in September and is ready by December or January. *Khehari cheena* (a kind of rice) and unirrigated maize are sown in May and harvested in August or September. This crop is totally dependent on rain. Sown in December and harvested in April or May, *Jethua khehari* is the crop most produced in this diara and it is cut four or five times.

Farming depends on the nature of the soil which, in turn, depends on the floods. *Domat* soil, a mixture of clay and sand, can support many crops but in this diara it covers only 10 per cent of the arable land. The thickness of the layer of *chakaa,* (sand and clay), determines the vegetables that can be sown. *Parwal* and pumpkin are sown if the thickness of this layer is between 15 cm and one metre. Bittergourd (*karela*) is sown if the thickness is between seven cm and 15 cm and watermelons if it is about 1.25 m. Most farmers of Shankarpur diara have to hire plows and bullocks. The cost of growing wheat on one bigha of land comes to Rs 725, which gives a maximum of 0.55 tonnes of wheat. The local merchant pays only Rs 125 for one quintal of wheat, which is about Rs 650 for 0.55 tonnes. Growing of irrigated and unirrigated maize is profitable. Farmers can hope for a profit of up to Rs 250 per bigha from this crop but, unfortunately, it is usually destroyed in floods. Vegetables and fruits also grow here. Parwal, pumpkin, bittergourd, cucumber and watermelon are sharecropped. These vegetables are sold in Bhagalpur and other towns.

Cheap diara vegetables are sold on Bhagalpur crossroads but this kind of retail selling is minimum. Town merchants have a monopoly on the vegetable trade and vegetables are auctioned at rates decided by them. Interests of the growers are not protected in these auctions. As a result, farming is an uncertain and losing proposition in the diara and peasants are forced to depend upon various sources of livelihood.

Rearing of cattle is common and milk is sold on a large scale in Bhagalpur and other small towns. There is no dearth of pastures in the diara but the animals are prone to disease and have a high mortality rate as there are veterinary no facilities.

The landlords of the diara are prosperous cattle owners. Their employees, called *Daihars* buy milk from small farmers and labourers at cheap rates. There are some daihars who independently sell milk in towns on a small scale. They take advances from the town shopkeepers in order to buy milk in cash.

Marginal incomes are obtained from labour in the farms, which is available for three to four months in a year. Men get double the wages given to women (Rs 6 and Rs 3 respectively). Men and women also often do contract labour in the towns or pull rickshaws. Women cut grass and sell it in towns and get barely Rs 2 for one bundle.

region leading to a political vacuum and government agencies have remained totally oblivious of its needs, the area has slowly moved towards entrenched caste groups and criminal gangs. Established political parties and social organisations have by now been absorbed by these networks. Criminal gangs form around caste networks and not only indulge in murder and dacoity but also caste wars. Today they have become so powerful that their support alone can ensure victory in the elections. As a result, a powerful combination of criminal gangs, landlords and politicians has emerged in the last two decades aided and abetted by the law enforcement authorities.

Litigation over land has become an integral part of life. Frauds in land measurement, looting of crops, local jealousies and violence have created an atmosphere to encourage it. Many families have been fighting cases for decades over small plots. Often over five to 10 times the contested price of the land ends up in the pockets of lawyers and court officials. The Shankarpur diara in Bihar is a glaring example of the rule of misrule. After zamindari abolition in the 1950s, landlords transferred hundreds of hectares of diara land in the names of their relatives and many poor farmers were dispossessed on the pretext that they had not paid their taxes. The 1960-61 survey divested the poor farmers of almost the entire land. The erstwhile landlords and new capitalists from the towns got most of it recorded in their names. Numerous frauds were played upon the poor to do this. Where a *bigha* in the diara was counted as containing 20 *kattha,* with each kattha measuring 99 inches, it came down to 80 inches to form the new bigha. The subsequent litigation was rigged by the influential landowners with the aid of false maps. The oldest recognised map of Shankarpur diara dates back to 1942-43 but it is not officially accepted. The poor farmers have been tilling their lands on the basis of this map but as it does not show any *khasra* number, the landlords got a new map prepared during the court case that followed. This showed the farmers' lands in the name of the landlords and their agents. Between 1975-76 and 1981-82, the Ganga changed course several times and about 1,500 bigha of new land emerged. There has been no survey or measurement of this land which is all under the illegal occupation of big landlords. Since independence no official map has been prepared to show the actual land position of the poor.

The poor farmers' lands also get grabbed on a large scale in the name of temporary land measurement surveys every year. A government official arrives to survey and measure the land and collects Rs 40-50 as *baksheesh* from the farmers. This measurement gets annulled the next year following floods and erosion. When the new measurement takes place, the small farmer's land gets added on to the holding of the big landowners. The ensuing litigation then goes on for years.

Instances of government connivance are rife. To cite one instance, in the Rani diara of Kahalgaon, about 4,000 bigha of land was thrown up by the Ganga in 1971. This land belonged to the Rani *panchayat.* After it became fit for cultivation, the villagers distributed it among themselves

each family being allocated land in proportion to what it had owned earlier. The big landlords, however, got wind of this and, with the help of criminal gangs, overran the area. When the villagers organised a protest, 60 of them were arrested and criminal cases filed against them. Murders and bullying are almost the rule in the diara areas and because of erosion and emergence of new land, disputes and struggles continue all the time.

A challenge to this powerful combination of criminals, landlords and politicians was posed by a Gangota called Kailash Mandal, today a legend in the area. At that time the Naxalite movement was at its peak in the area and Kailash Mandal, who had earlier lost his land to a powerful landlord, decided to form a criminal gang of his own. Though Kailash Mandal was also a criminal who indulged in murders and dacoities, his targets were mainly the upper caste, wealthy landlords. Mandal organised the poor Gangotas and Yadavas into powerful gangs[155]. In March 1971, a clash took place between Kailash Mandal's gang and a local landlord who wanted to dispossess the Yadava-Gangota sharecroppers in Kathaila village. The landlord and about 10 of his people were killed. Kailash Mandal and his violent activities became the talk of the state. While the police searched for him, the diara people gave him refuge and began to follow him in hundreds to loot the landlords and the moneylenders. Journalist Mukul Sharma of *Navbharat Times* writes that the activities of Kailash Mandal terrorised the diara outsiders and the upper caste landlords. The murder of the powerful landlord in Kathaila is a living legend today in diara villages.

It is said that Kailash Mandal was able to get 1,600 ha of land freed from the control of the powerful landlords. In 1977, however, he was killed by a gang member and his gang taken over by Hari Mandal but he was also killed soon. The gang was finally taken over by Sudama Mandal.

The combined strength of the police, Central Reserve Police Force (CRPF) and local landlords was too much for Kailash Mandal and he had to flee for his life to Nepal. After that, the terror of the landlords' increased to such a point that many people had to join criminal gangs to escape their wrath. After Kailash Mandal died, police and the criminal gangs tried to kill off his colleagues one by one. The fear of the police and other criminal gangs went on increasing and, in this period, numerous new gangs emerged. Today the situation has reached a crisis point where every single group believes that it can be protected only by a criminal group of its own. So, in the diara now, there is a criminal gang everywhere — "somewhere it is a Bhumihar gang, somewhere a Yadava one, a Dhanuk one, a Koeri or a Bind

ALL FOR SHOW AND PROFIT: Police patrolling the diara areas of Bihar. (Krishna Murari Kishan)

SAVAGE HARVEST

The shifting sands of the *diara* have tasted human blood on more than one occasion. The savage massacres of the diara lands have repeatedly shocked the nation.

On January 4, 1984 nine *Yadava* children, one youth and a 60 year old man walked into on ambush laid by a group of 40 *Dhanuks*. The unsuspecting people had gone across the river to collect grass and deliver food to those working in the fields. This incident later became known across the country as the Piparia massacre of Munger district[1,2].

Three children who survived the ordeal and returned 72 hours later described the blood curdling manner in which they were beaten and the rest killed after being packed into a boat.

The incident was not unexpected. On the contrary, it was long overdue. The Yadavas had dared to be witnesses at the murder trial of one Rameshwar Yadava who had been killed in 1983.

A stretch of new land that had become available for cultivation after the floods was the root cause of the dispute between both castes. As a result, in 1982 Rameshwar Yadava's son was killed by the Dhanuks. A year later in 1983, the vengeful Yadavas killed four Dhanuks, which resulted in a Dhanuk reprisal that claimed the life of Rameshwar Yadava.

All the victims of the January 1984 massacre were from the families that bore witness against the Dhanuks in the murder trial. Amongst the dead was one Dhanuk by the name of Bhagwan Rai, whose father had been labeled a traitor because he had testified against his caste.

In the aftermath of the Piparia incident, the police response was characteristically slack. Even the bodies could not be recovered and the families had to carry out cremation rites with straw effigies.

Even before 1985 was out, a mob of Yadavas descended upon the village of Laxmipur-Taufir in Munger district killing at least 20 people, burning and sacking about 300 huts and leaving about 2,200 people homeless. In fact, the villagers were so terrorised that nobody was even prepared to say how many died. The toll could even have been a hundred or more. As local villagers told *India Today* "They came from all sides, on horses and on foot, carrying weapons and guns, and fell upon the village like vultures. They did not spare anything or anybody."

Land grabbing was allegedly again at the root of the massacre. A *Rajput* landlord had given about 50 ha of land to a Yadava farmer for sharecropping, who tried to usurp the land. When the landlord found it difficult to recover it, he decided to give the land to a powerful *Bind* on a sharecropping arrangement. The Bind tried to cultivate the land and clashed with the equally powerful Yadava and tension mounted in the area. On November 11, some 600-700 people led by the Yadavas attacked the Bind village of Laxmipur-Taufir and razed it.

one," as journalist Mohan Prasad puts it.

At that time Kailash Mandal was expressing the anguish of the diara poor through his criminal activities, numerous political struggles were also taking place within the diara region by sharecroppers for their rights. But the political system failed to pay any heed to these movements.

Mukul Sharma warns that it would be wrong to conclude from Kailash Mandal's example that there are several gangs fighting for the poor against the landlords. Kailash Mandal has remained the only example of his kind and he, too, was not a social reformer. His basis was intensely casteist and his activities criminal. Kailash Mandal was, therefore, able to terrorise some landlords but their strength was not diminished. Except for Kailash Mandal's, every criminal gang in the area has worked for them and serves their interests.

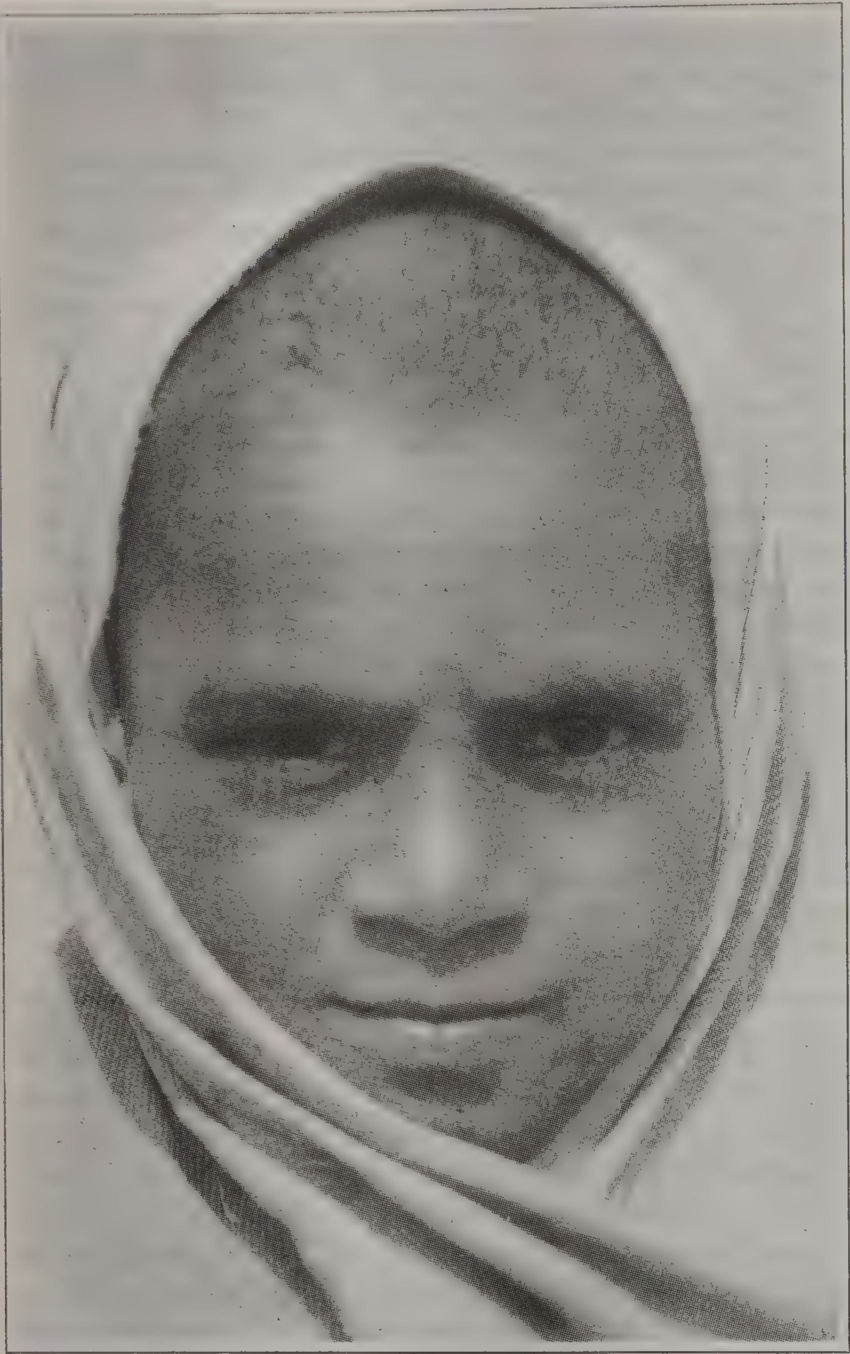
Land and other natural resources in the region are controlled by the big landlords and urban capitalists through these gangs. No other part of India has such a strong nexus between criminal elements and the control of an area. As new land emerges from the river, these gangs takeover, dispossess peasants and sharecroppers, loot reluctant sharecroppers' crops, protect the lands of big landlords, and get illegally acquired lands cultivated.

These gangs even manage the *ghats* along the river. The diara peasants who come to Bhagalpur town, for instance, to sell vegetables and milk on boats, have to use these ghats. There are numerous ghats in Bhagalpur but they are all managed by one family, which makes enormous money from boats. The government boats that plied earlier have now stopped. This family manages a few big ghats itself but it contracts out the smaller ghats to various landlords, who then operate them with the help of their hired *lathi* wielding men. They operate their own boats and extort all kinds of ghat levies. There is great rivalry for profits among these contractors. To keep their own ghats functioning, they will organise the looting of other ghats. In a few years, one person of Shankarpur Athgamma village has established complete domination over the ghats. Shankarpur ghat is today regarded the safest while others remain vacant because of the fear of dacoits and violence. Levy is charged at will on goods going from Shankarpur ghat to the town.

The gangs also control the illegal trade in sand, stone and silt from the diara from which they make unlimited sums of money. They also extort a *rangdari* tax from farmers, fisherfolk, milk sellers and other small producers. In this way, the criminal gangs control literally all productive activities in the area.

While this has helped landlords and urban capitalists to control the region from the background, the growing power of the criminals through political control and acquisition of modern weapons is making them increasingly irrelevant. The criminals no longer need the support of their erstwhile masters and, as a result, their direct influence on civic administration has grown.

The 1980s have repeatedly seen mass murders in the diara — in Abaiya in 1980, in Piparia in 1984 and in Taufir in 1985. The Abaiya massacre in Munger district did not take place in the diara but in an area close to it. It was the result of a caste war between the Brahmins on one side and the Koeris and Yadavas on the other. Dozens died in the massacre. The most gruesome massacre took place in Piparia where a Dhanuk gang killed 14 Yadava children and threw them into the Ganga. Some 35 people were killed in the Taufir massacre (see box). An estimated 1,500 people



THE FACE OF THE DIARA: The harsh environment of the diara brings about a look of maturity on the face of this child. (Amar Talwar/CSE)

Table 56

Basic information about Taufir Diara[1]

Total population	28570	
Total area (ha)	7050	
Total cultivated area (ha)	4000	(57%)
Total households	4062	
Landless households	1693	(42%)
Landowning households	2369	(58%)
Marginal	576	(14%)
Small	1061	(26%)
Big	732	(18%)

Note : [1]The Taufir diara in Munger district consists of three villages: Taufir, Laxmipur-Taufir and Tikarampur.

Source : 160

have been murdered in the five years between 1982 and 1987 in the diara areas of Bihar[155].

The gangs vie with each other to control the emerging land, and margangs and to collect the rangdari tax. This competition often converts into a caste war and in the process

BLIND BHAGALPUR

The pathway from the Bhagalpur railway station towards the river is overlaid with rubbish, writes journalist Arun Sinha in *The Illustrated Weekly of India*[1]. There is the nauseating stench of raw cotton, spices and garbage in the bazaar, intermingled with the smell of fear hanging like a mist over the criminal locality of Mundichak and the mónotony of, banal and small town houses. The stench and the terror dissipates once the Sandees compound, the town's central *maidan* around which bungalows and nice houses are located, has been reached.

Years ago, the town was pitched upon Champanagar, the town of famous weavers. Today, Champanagar, makes up the poorest part of Bhagalpur. With the coming of powerlooms a weaver's daily wage is no longer linked to the hours of work, but to the yards of cloth he produces. Fitful electricity supply makes things difficult and the weavers poorer. Poverty and darkness together create an atmosphere of insecurity among those residents of Bhagalpur who have anything of worth, on their bodies or at home.

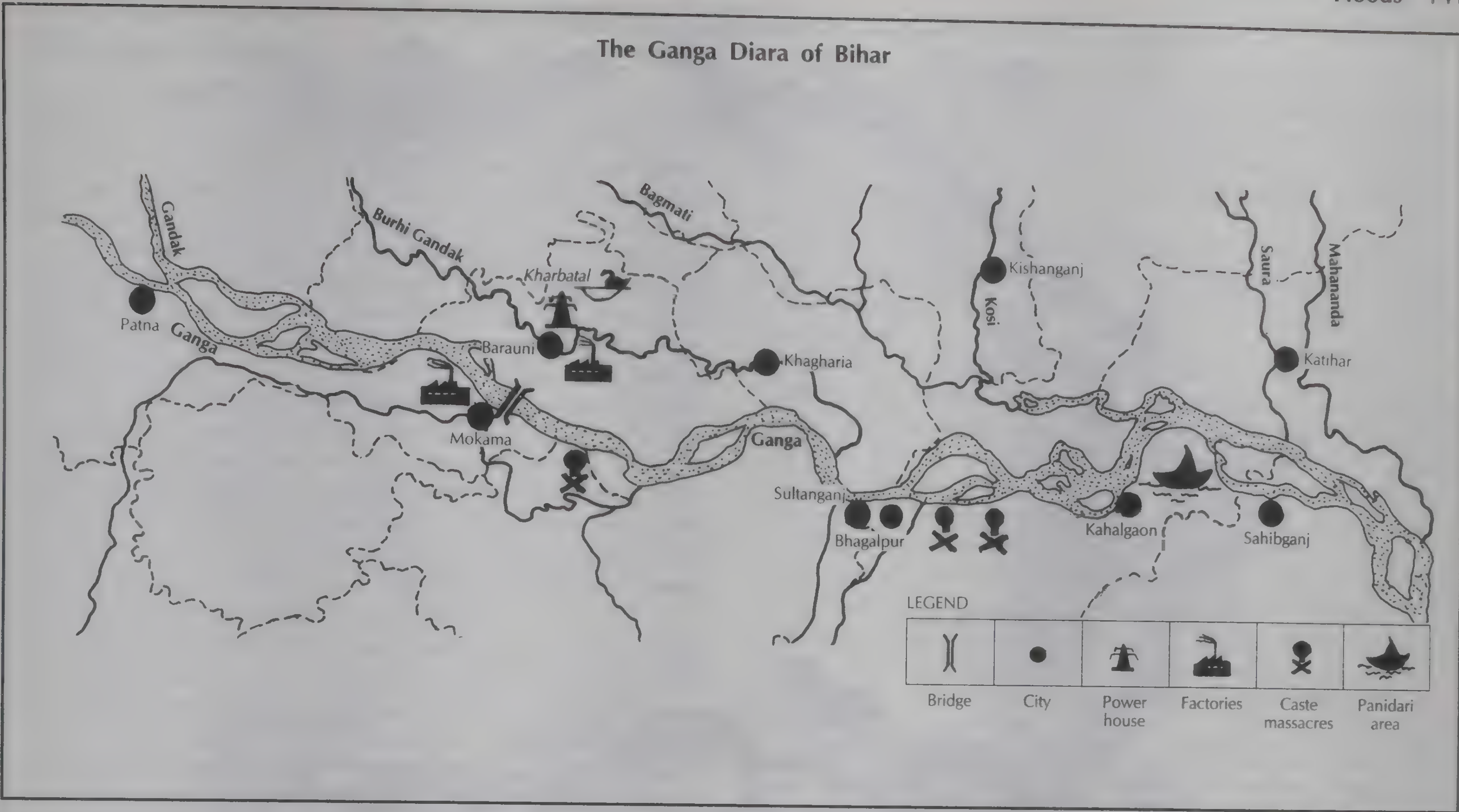
The rural areas of Bhagalpur district, especially the *diara,* are largely worked by sharecroppers and looked after by musclemen for rich landlords. Many of the landlords live in Bhagalpur and nearby small towns. A few of them are *Marwaris* who have succeeded in business; some are lawyers, others politicians and teachers. Sometimes, the sharecropper may demand, even seize, a part of the land. Thieves can cart away ripe crops from the fields at night. The main robbers of the area demand protection fees. But, landlords are not men without ideas. Over the years, they have learnt to keep their own gangsters, of which the rural society provides a constant supply.

When police officials of the Bhagalpur district began to blind 'criminals', Sudama Mandal, a young *Gangota,* was the top diara gangster. Generations of Gangotas and other lower castes had borne the *Bhumihars'* oppression quietly. Sudama Mandal refused to do so and killed a few of the leading Bhumihars. He became famous within a short span. The landlords and the police began to enter his name in almost every first information report, even in those lodged at police stations where Sudama had never operated. People soon concluded that the district was controlled by criminals.

Fear had become such a way of life in Bhagalpur that when the police began blinding suspects, the public wholeheartedly supported it. In this campaign, truth was the first victim, says Sinha. A group of people would bring someone to the police station, and the police would take him to be a criminal without any inquiry. A group of policemen would catch someone and blind him, and people would believe he was a criminal.

Most of those blinded were not the ones the diara dreaded or the town feared. As a matter of fact, many of them had no case records. Blindings were an ingenuous short cut to crime control for the police. Most policemen believed they were making a public display of their power — for them a sure way of restoring the credibility and authority of the administration.

The blinding incidents revealed a deep nexus between the police and the rich. Sudama Mandal was the enemy of rich landlords, so the police hunted him. Had he been on the side of the landlords, police would never have hunted him. In the name of 'public cooperation,' policemen found an easy way to work in collaboration with the dominant class. Almost all those blinded belonged to lower castes. A few of the upper caste criminals were also caught by the police but they were merely sent to jail.



numerous innocents get killed. Human life is at a very low premium in the diara of Bihar. Mukul Sharma claims that there are criminal gangs in the diara which kill human beings by cutting them from head to feet in small pieces.

The role of the police has also been extremely negative in the area, as it is seen aligned with the powerful people in the local society. It perceived the gang of Kailash Mandal as a threat and did everything to terrorise the diara inhabitants in its bid to destroy his gang. The isolated incidents of violence by Yadava and Gangota gangs brought to bear an organised reprisal by the police and powerful landlords in the area. So terrorstricken were the inhabitants of Bhagalpur town by the activities of Kailash, Sudama Mandal's and other such gangs, that they wholeheartedly supported the barbarous blindings of petty criminals by the Bhagalpur police. As journalist Arun Sinha writes, people strongly believed that the entire district was controlled by criminals and were prepared to support any act against them[156] (see box).

Despite all this, the problem of land tenancy, the root of the crime problem, remains untouched. Newspapers repeatedly name landlords who illegally own and control thousands of hectares of diara lands. Over 70 per cent of the diara land is said to be sharecropped[154]. The government has, however, failed to treat the problem as anything more than a law and order issue.

ECOLOGICAL CHANGE

In addition to uncertain land tenancy, the economic problems of the diara people are multiplying because of changing ecological conditions. The people believe that the problems of floods, waterlogging and erosion in the diara areas are becoming worse.

The people of Bhagalpur, Munger, Naughachiya, Kahalgaon, Purnea and Katihar diara say that for the last few years, floods have been reaching the diara earlier than before, and the entire *bhadai* crop which is reaped in the month of August, gets destroyed. Flood waters also stay longer with the result that the rabi crop gets delayed and production falls. According to villagers, the force of the floods has increased, and because of their extraordinary fury, loss of life and property has increased. All Bihar diara residents agree that the 1987 floods were the deadliest of the century. The older people say that they had never seen such fury and such massive erosion.

In a hard hitting article in *Gandhi Marg,* Nirmal, a local social worker points out that the construction of an embankment to protect the new industries in the town of Begusarai along the Ganga has intensified the problem. "Earlier, floods would spread over a 20 km area but now they get hemmed down to a length of two km. Between Barhadiya and Bariapur, an area of 30,000 ha has been torn apart. The floods that come now are called 'mad floods' by the local people. Their level is at least one metre more. The area covered by sand and water has doubled. About 25,000 families have had to leave the diara and now live in little huts along the road from Patna to Bhagalpur and Munger," says Nirmal.

"Has anybody calculated the arithmetic of these results," asks Nirmal. "It is not very long ago, only 40 to 50 years ago, the diara area was considered a gold mine. Sweet pea was animal fodder here. Horses were fed all kinds of cereals. Milk used to flow all round. But now the entire area, which once supported over 0.2 million head of cattle, has been destroyed."

Villages upon villages were swept away. Earlier, villages on higher lands were safe from erosion for years together.

The villages of Karar diara also face the threat of erosion now. The Ganga was so far away from there that nobody ever thought the village could be eroded[157,158].

Delayed waterlogging after the floods has also claimed a lot of arable land as the river banks get covered with sand. In a study of the Sabour diara of Bhagalpur, the Indian Agricultural Research Institute has found that when the floods last longer, the sand cover becomes deeper (see table 57). This land yields only a few vegetables and is not very fertile. With an increased duration of waterlogging, there has been an increase in sand covered land, rendering it useless for many years. It is believed that floods increase fertility of the soil. This reduces the cost of fertilisers and irrigation. That is why diara farming has been called the cheapest form of farming. But the residents now say this is being proved wrong. Production in the Sabour diara area has declined. The land is becoming sterile. Farming has become unproductive and uncertain and more than ever before the people find themselves displaced. Thousand of hectares of diara land has been lost in the last 100 years. Since the landlords own land in the plains also, there is no noticeable change in their condition, but the livelihood of a majority of the poor of the diara is being threatened.

Very little land seems to have emerged out of water compared to the amount lost to it. Most of the newly emerged land is not yet fit for agriculture. There are no figures available for the diara land submerged and the land thrown up. A survey of Vikrampur in Bhagalpur and Lalganj diara in Purnea reveals that almost all the arable land of these villages has been claimed by water, but no land has emerged of late.

Table 57
Sand accumulation during waterlogging

Duration of waterlogging (days)	Sand accumulation (cm)
15-30	2.25
30-45	5.83
45-60	8.33
Over 60	6.25

Source : 159

Other side effects are also being felt in the diara. For the last few years, there are fewer fish in the Kosi and Ganga. At times, large numbers of dead fish have been found in many spots in the Ganga. With decreasing fish production, the livelihood of the diara fisherfolk has been affected. Cattle rearing has also declined. Because of the loss of agricultural land through erosion, there is pressure on farming areas and, as a result, pastures are fast dwindling. In some diara areas the practice of cash crops has been introduced, which does not leave anything for feeding animals. Shortage of fodder has led to a fall in milk production. Livestock mortality is also high because of disease.

These problems can be traced to the increasing pollution in the rivers, the felling of trees, wrong planning of bunds and embankments, and neglect by the government. The

THE KILLING FIELDS

The *tals* are natural depressions which receive flood waters during the monsoon months. According to the Rashtriya Barh Ayog (RBA) such areas must not be reclaimed for agriculture. In Bihar, however, tal areas are already so coveted that they have become major sources of disputes, writes Rajiv Ranjan Lal in *The Illustrated Weekly of India* [1]. The tal area in south Bihar is a strip of saucer shaped land south of the Ganga embracing parts of Patna, Munger and Nalanda districts. It is the biggest *dalhan* or (pulse) producing belt in the country. The rain water and the overflow from seven rivers — Jiragaon, Kumbher, Mohani, Hattar, Panchanwe, Goethwa and Punpun — which flow into the Ganga, submerges the area every year. This cuts off the region from June to September which is a boon for landlords who have been trying to evict the tillers since 1973, when an act giving ownership rights to tillers was passed. The act is the bone of contention in the tal area, the reason why the landlords and tillers are at loggerheads. Murder in these villages is now an everyday occurrence.

Violence began in 1973 when landlords started organising anti-social elements to evict the tillers. The tillers resisted the eviction and moved the local court at Barh in 1976, but the court's verdict in 1978 went in favour of landlords and it gave them the right to evict. The tillers filed a writ in the Patna high court the same year which reversed the earlier judgment and asked the DCCLR to look into the matter afresh. This tug of war in the courts has only increased tensions.

As might became right, landlords organised *bichaulias* (middlemen) or private armies. The *Bhumihars, Kurmis* and *Rajputs* are major landlords. *Yadavas,* who constitute 30 per cent of the population, are small landlords or labourers, while *Dhadis* (a backward caste) and *Harijans* comprising another 30 per cent, are tillers. To counter tillers' resistance, landlords have recruited a number of Yadavas and Dhadis to provide muscle power.

On Christmas eve in 1989, the tal wore a melancholy look. After the Lok Sabha elections, the terror had recommenced. In Sehri village of Mokama tal, hoodlums looted a tiller's crops at gunpoint.

There is a flagrant violation of the act on rural land ceiling in this area. Several landlords own not less than 400 ha of land each. The last land survey in Bihar was done in 1909. The agrarian tension has led to criminal activity with two rival Yadava gangs operating in the area. Tal residents have no faith in the police. There is no rule of law in the area. Labourers have to be content with a wage of Rs eight for men and Rs five for women. The terrorism that prevails in the area is concentrated in the towns of Mokama and Barhaiya which are marketplaces for the tal produce. Two gangs of Bhumihar criminals are active in each of the two towns. They collect *rangdari* tax from shopkeepers at gunpoint.

With the landlords gaining ground, many labourers have fled and settled down in Patna. In 1986, the government constituted a committee to look into the problems. The committee suggested measures like preventing waterlogging, and provision of electricity and irrigation for summer cropping. But if the recommendations were implemented, would the poor tillers or the local ecology benefit?

Farakka barrage hampers the migration of fish and even prevents certain species from going to the upper areas. One such example is *hilsa* fish. The natural habitat of the hilsa is the sea but it comes upstream in the Ganga to spawn. Very little hilsa is now found upstream of Farakka. The fall in fish production has hastened the ruin of the Diara fisherfolk. Their financial position has further deteriorated.

A study by Bhagalpur university shows that in the 256 km between Barauni and Farakka, the Ganga is the most polluted near the Mokama bridge. Here industries like the Bata shoe factory, McDowell Distillery, an oil refinery, a thermal power station and chemical fertiliser factories discharge their effluents into the Ganga. Some experiments to gauge the poisonous nature of this part of the river have revealed that fish introduced into the Bata area water die in 48 hours, but in the McDowell area water, these die within five hours. The effluents of the oil refinery are so bad that at one time the Ganga went up in flames near Munger. Due to the increasing pollution and considerable rise in coliform bacteria, the river water has become less potable and waterborne diseases are reported to be on the increase in the diara. Mortality rates of fish are also reportedly increasing[152]. A study by Bhagalpur university shows that because of pollution, spawning has declined significantly[155].

Apart from industrial pollution, more than 120 bodies are cremated on the banks of the Ganga at the burning ghats of Bhagalpur, Sultanganj, Munger and Simaria. The high level of pollution in the Ganga from Patna to Bhagalpur may be one reason why the water is making the diara land sterile, and agricultural efforts are becoming unproductive.

Not only is the Ganga getting polluted but siltation in it is also rising. From Patna to Farakka, the Ganga carries a great amount of silt which is piling up in the river bed at different places. As a result, thousands of hectares of diara land is getting covered with sand. The river bed is also rising due to industrial wastes.

Indiscriminate felling of forests has spoilt the environment of the diara. There has been illegal clearing of diara forests on a large scale. Once there was an abundance of rosewood trees but now the area has been mostly cleared of these trees. Earlier *babul,* plum and *jalebi* trees were also found here. These provided firewood and helped to bind the soil, now these are barely visible. The pastures of jhaua and kash grass have also been cut increasing the danger of floods and erosion. Jhaua and kash are wild grasses, which can survive waterlogging, sterility, salinity and even strong winds, thus, binding the diara land and preventing erosion. The newly emerging land is usually left to jhaua and kash for some years so that it becomes fit for cultivation. But because of the increasing pressure on agricultural land, these grasses get destroyed fast, in the competition to quickly remove these grasses and cultivate the land. Commercial exploitation of jhaua and kash has also begun by making ropes out of it.

The problem of waterlogging and poor drainage is increasing because of the embankments built to protect the towns and because of the existence of national highways and railway lines. A few days of heavy rain in the diara of

COVETED ISLANDS

Bangladesh is a country with numerous rivers, which have repeatedly changed course, eroding banks, submerging old land and making new ones. The newly accreted lands are known as *char* lands, meaning small river islands. In densely populated Bangladesh, these are highly coveted. Each year nearly a million people are affected by erosion. The displaced numbers add to the considerable landless population of the country creating serious problems of rehabilitation.

The amount of accreted land is significant. From 1940-1963 about 107,700 ha of land was eroded and 135,600 ha was accreted. Apart from natural accretion, emergence of land can get accelerated due to construction of cross dams. In the Ramgati and Char Jabbar region, accretion has increased with the building of two cross dams across the Meghna.

The problem lies in the apathy of the government towards the plight of those displaced and its inaction against local landowners *(jotedars)* who grab the chars through violence, trickery and unjust means.

S M Nurul Alam of Jahangir Nagar university has carried out a study of settlement problems in char lands[1] which indicates that as new land gets thrown up by the river, violence is used to grab the land. The landless get pushed aside in this mad grab.

New land legally becomes the property of the state but the government's inability to ensure systematic rehabilitation of the landless makes it easy for the jotedars to enforce their rights by effective use of property brokers. The local daily *Itefaque* reported 134 char clashes in the period 1971-80. One analysis reveals that a total of 733 people have died in violent clashes and most of them in Noakhali. In three separate incidents, 4,300 *lathiyals* were used and 1,308 houses were burnt in Noakhali. A local person called Khailullah was notorious for terrorising the poor in char areas and in one instance reportedly gouged out the eyes of his victim. In June 1978, an entire char was depopulated leaving over 500 dead. Nurul Alam believes that the frequency and cruelty of violence has increased significantly in recent years.

A presidential order was passed in 1972 which made all newly accreted lands government property. This order was encouraging for the landless. But in 1975, the order was amended to state that the new land will be restored to the previous owners only if the land reappears in the same place within 20 years. Otherwise people living in nearby areas will get preference. This opened the way for jotedars.

As new land gets accreted, jotedars stake a claim over it. The allotment forms for the land are sold at a nominal price by revenue officers who are hand in glove with the jotedars and let them have most of the forms. The result is blackmarketing of the forms at high rates or allotment of land to jotedars against signatures of the landless who sign in the hope of allotment.

A pilot project, under the aegis of the governments of Bangladesh and the Netherlands, was carried out to settle those who had been displaced by earlier changes in the river course on a new island called Char Baggar Dona in Noakhali. The agreement was signed in 1978. But it was only in 1983 that it was officially decided to lease about 1,100 ha to 30 cooperatives of the landless. After much delay, the minister for land administration and land reforms, handed over 133 ha to five cooperatives. However, until February 1985, no concrete result was forthcoming. After many attempts by land grabbers to jeopardise the entire project by using their political contacts, the landless were allotted land in June 1985, nearly six years after the initial agreement.

DEPRIVED DUO : Their home under water two Bengali boys weather the wrath of nature. (UNICEF/FAO

MEERUT'S KHADAR

The district of Meerut in western Uttar Pradesh is fed by three perennial rivers — Ganga, Yamuna and Hindon. Their beds form vast *khadar* tracts. A study carried out by C. Mumtamayee of Miranda House in New Delhi which she undertook for her Ph D, describes in detail how humans survive in this habitat[1].

These khadar lands, however, are under a threat, in recent years, the influx of outsiders has been increasing. They have begun to buy land in the khadar to grow rich crops. Truck drivers plying in the area keep an eye out for available khadar lands. This influx has created a gap between the relatively well off outsiders and not so well off local people. If this trend is not checked, the area could easily begin to see violence and land disputes like Bihar.

Most people in these areas depend upon farming and cattle rearing for their livelihood. They manage to raise at least one *rabi* crop in a year. The *kharif* crop always runs the risk of being washed away by floods — a regular feature in the khadar. The local people possess a lifestyle that is geared to survive even in the face of it.

Floods bring about temporary displacement. The displacees then seek temporary shelter in safer areas. They move to higher lands known as *bhangars*. The villages providing temporary shelter are able to accommodate the displacees because they usually have non-land occupations or marginal farming, which does not get severely affected by the sudden influx of people. In case of a wide river bed, the khadar people move to areas within the river bed which do not get flooded. The khadar inhabitants build slightly raised houses on plinths which means that in case of a low level flood, they do not have to move out at all. They will sometimes spend days on a pole platform or even on a *jhoola* (swing) suspended from the trees. Some huts also have thatched roofs, which can be used as a float in case of a sudden rise in water.

During floods, livestock are herded out to safer places while men stay on with some supply of food. During periods of heavy floods, the khadar people survive in the shelter villages by selling milk. Able bodied men go off to nearby towns to look for manual work whereas women and children stay on.

Population levels of khadar settlements change rapidly. When an area gets flooded, the population of nearby shelter villages can double or treble overnight. The return to the abandoned tracts is much slower. As patches of land emerge, people return to it in batches. An abandoned village can sometimes get reclaimed after four to five years. But it is usually never the same.

The complex pathways between khadar and bhangar villages, are understood by the local people very well though they are very marshy and difficult for outsiders. These pathways determine communications and contacts with outer towns and villages. Very often, two khadar villages will not have a route linking them because they have nothing to barter with each other.

Khadar people are farmers and they cultivate small areas of land. They also rear cattle and sell milk and milk products. They grow whatever is saleable in the nearby towns. Cultivation of sugarcane gives them cash so they grow a lot of it for sale to sugar factories of the area. They also grow vegetables like potato, sweet potato, tomatoes and cucurbits. Marketing is not a problem since trucks ply in the area. Irrigation is a problem but it is now being met with the use of diesel pumps. Traditional means of lifting water from the river are no longer in use. People in the area have no access to electricity, schools or hospitals. Water borne diseases and malaria are common.

The inhabitants of the Meerut khadar are fairly self sufficient. They are able to cope with the floods quite well and, in fact, it is a way of life with them. Inhabitants of a riverine village near Delhi were recently offered an alternate site but as the flood waters receded, they returned to their original home.

The khadar people live under a constant threat of impoverishment yet manage to make ends meet. It is only with outside intervention that problems arise. For instance, the increase in sugar and garment factories has led to the building of numerous low level bridges across river channels. This has led to a permanent displacement of boat owners who used these rivers when bridges did not obstruct their passage.

Criminal activity is not much prevalent, through a lot of criminals do find it convenient to hide out in these areas because police find it difficult to enter them.

Unlike Bihar, local land disputes, despite the regular emergence and submergence of land, are remarkably few. Villagers are aware of their land boundaries and even in cases of inundation lasting over several years, no fight over land takes place. Villagers settle their disputes themselves. Courts, find it impossible to deal with khadar cases because lawyers cannot understand their concepts of land boundaries.

Ganga, Kosi and Gandak leads to waterlogging everywhere. At some places, water remains for three months in a year, and at certain other places, for six months or even the entire year. Construction activity has led to the narrowing of waterways, water exits have been closed and most sluice gates have become useless. Many Kosi and Gandak project areas and many large diara areas in Purnea and Katihar districts, have become permanently waterlogged. In Naughachiya area of Bhagalpur, embankments have been built for roads, railways and canals but have not been provided water exits. The result is that diara areas now face heavier submergence. Waterlogging has led to water shortage, diseases and fodder shortage.

It is clear that the millions of people inhabiting the diara and khadar lands of India are suffering not only the vicissitudes of the inherent ecological conditions of these areas but also the adverse impact of increased pollution, deforestation and depletion of fish. The government has failed to approach the unique problems of diara land with any imagination. The country's rural development programmes have failed. Without land surveys and governmental will to implement laws, the diara have become regions of extreme violence and despair. Areas like the khadar of western Uttar Pradesh, which do not witness such violence, are beginning to report disquieting trends (see box). Activities undertaken to promote development in the plains next to the diara, such as the construction of bridges, roads and embankments have often had a negative impact on the inhabitants.

Learning to live in the flood plains is a concept that India is still to understand. Social indiscipline, government incompetence and corruption have only bred ecologically unsound land use practices, social apathy and criminal activity in the diara.

- *The idea that nature can be conquered carries within it the seed of human destruction. The onus of adaptation lies on human society and not on nature.*

- *People in the plains must learn to live with floods which bring with them several ecological advantages.*

- *Floods are not new to the Indo-Gangetic plains. Ganga, Indus and Brahmaputra valleys were flood prone even when there was plenty of green cover in the Himalaya.*

- *Ancient Indians carefully built cities like Varanasi, Prayag and Pataliputra near relatively stable rivers, rather than flashy ones, and on safe sites.*

- *The environmental argument that Himalayan deforestation is a major cause of 20th century floods is giving rise to bad politics — corrupt and bad governments in the plains blaming the poor in the hills to hide their own ineptitude.*

- *Just as Himalayan farmers must respect the role of forests in their environment, the farmers in the plains must respect the role of floods. Each must learn to live in harmony with the local ecology.*

- *Flood plains management in India is conspicuous by its absence. Very few environmentalists or government agencies have cared to study and develop ecologically sound management systems for the flood plains.*

- *Most recommendations of the Rashtriya Barh Ayog like watershed management, flood forecasting and regulation of settlements exist on paper. Stress remains on engineering responses.*

- *Ecologically sound management of the flood plains poses an enormous social, political and technological challenge. In the Indo-Gangetic plains lives one of the world's largest concentration of humans, especially poor humans. Managed well these lands can feed half of Asia. Otherwise there can be mass hunger.*

CHAPTER 7

A Truce with Nature

The idea that nature can be conquered and transformed according to human wishes carries within it the seed of human destruction. The central objective of the global environment movement is to urge human society to live in harmony with nature. The new environmental ethic treats nature as that overarching entity in which all of us survive. It must, therefore, be treated with respect and transformations must be gentle, non-violent and sustainable. The onus of adaptation lies on human society and not on nature. In other words, people who live in the flood plains must learn to live with the perennial problem of floods. Floods are not entirely a bad phenomenon. They also bring several ecological advantages.

The environmental debate on the subject of floods, in the Subhimalayan region, has tended to be gravely misplaced. Indian environmentalists have argued that destruction of forests in the Himalayan uplands have greatly exacerbated the problem of floods in the plains. Available scientific evidence shows this argument to be an exaggeration though the situation may be different in other river basins with different hydrological, geological and soil conditions. The Indus, Ganga and Brahmaputra valleys have always been flood prone. Even when the Himalayan mountains were uninhabited and the forest cover intact, major floods visited these valleys and disrupted human civilisation. Ancient Indian literature is full of references to devastating floods. People who built cities like Varanasi, Prayag and Patliputra were faced with a dilemma. They wanted to be close to the major rivers, which were the arteries of communication and commerce, they were also afraid of the floods these would bring. They, therefore, carefully chose the site of their cities along more stable rivers and on relatively flood proof bluffs. As a result, some of these cities have lasted for thousands of years whereas major cities could never emerge in other areas where rivers were flashy and volatile.

The Himalayan mountains, being the youngest in the world, lashed by intense rainstorms and highly seismic, give rise to extremely flashy rivers which come down laden with enormous quantities of silt. This is inherent to the ecology of the Himalayan ranges, and floods, therefore, are inherent

DAILY CHORES: Life goes on despite floods. Women of Rajasthan forage for fodder even when there is knee deep water. (Steve Jackson/UNEP)

FEAR FACTOR

Fear of floods has greatly determined the pattern of urban settlements in the middle Ganga plains, according to a study by S C Singh of the Benares Hindu university. Each year, floods devastate large areas of the Indo-Gangetic plains, submerging cultivated lands, settlements, and causing changes in the courses of the flooding rivers.

The middle Ganga plain is traversed by the Ganga and four major tributaries, namely, Ghaghara, Gandak, Kosi and Son. Most rivers in the Ghaghara system have shifting channels and are notorious for dangerous floods. The Gandak system with its changing courses and floods has usually proved more disastrous than even the Ghaghara system. The Kosi, the sorrow of Bihar, is another cause of disastrous floods and changing courses. The Son, too, used to inundate the neighbouring low lands till the construction of the Son canal. Other perennial rivers like the Kamla, Bagmati, Burhi Gandak, Rapti and Gomti, too, have shifted their courses over the years. On the contrary, the Ganga is well known for its modest number of bifurcations with slow changes along its course including places of eminence that have provided favourable town sites.

From the time of the Aryans, cities have flourished along the banks of rivers — Prayag, for instance, on the confluence of the Ganga, Yamuna and the invisible Saraswati; Kashi on the confluence of the Ganga and Varuna; and; Ayodhya on the banks of the Ghaghara.

With the growth of population, several other towns came to be established on navigable rivers. Topographical features like a bold bluff along the river meander were selected as suitable town sites. King Ajatsatru deserted Rajgir as a capital in favour of Patliputra, situated on an important bluff on the Ganga, nearly 2,500 years ago.

Out of the 120 towns that originated during or before the medieval period, 79 were located along rivers. Some 30 per cent of these riverside towns are located along the Ganga. Out of 10 class I cities, six are located along it (see table 1). There is a long row of towns along the Ganga — Allahabad, Mirzapur, Varanasi, Ghazipur, Ballia, Chhapra, Patna, Hajipur, Dinapur, Mokama, Munger and Bhagalpur. Of these only Ballia has been flooded three times with the northward shift of the river. Its present site too is threatened by flooding.

Changes in the course of the rivers have either been advantageous to the towns making them suitable sites for urban sprawl or have led to their destruction altogether. Patna, situated at the confluence of Gandak and Ganga, has suffered river erosion on several occasions. From 1541, however, when Shershah built modern Patna, there has been no appreciable change in the course of the Ganga.

Because of their violent character, other rivers have seen the growth of few towns except where bold *kankar* reefs occur along their banks against which the river courses have stood stable for a long time — for instance, Ayodhya, Tanda and Barhatganj on the Ghaghara; Bagha and Lalganj on the Gandak; and Purnea on the old Kosi.

Many old market centres which had the potential to grow were estranged by the shift of the Ghaghara. The 10th century town of Bhagalpur in district Deoria and the medieval city of Gazanfarabad were washed away by the Ghaghara and embedded by the changing river course. Except for Purnea, not

Towns in the middle Ganga plains

Category of Towns	No. of towns (1961 census)	No. along river banks	No. of towns along the Ganga: Actual	No. of towns along the Ganga: % of towns along river banks
Class I	10	10	6	60
Class II	8	6	2	33
Class III	28	20	6	30
Class IV	41	24	5	21
Class V	32	18	4	22
Class VI	1	1	1	100
Total	120	79	24	30

Source : 1

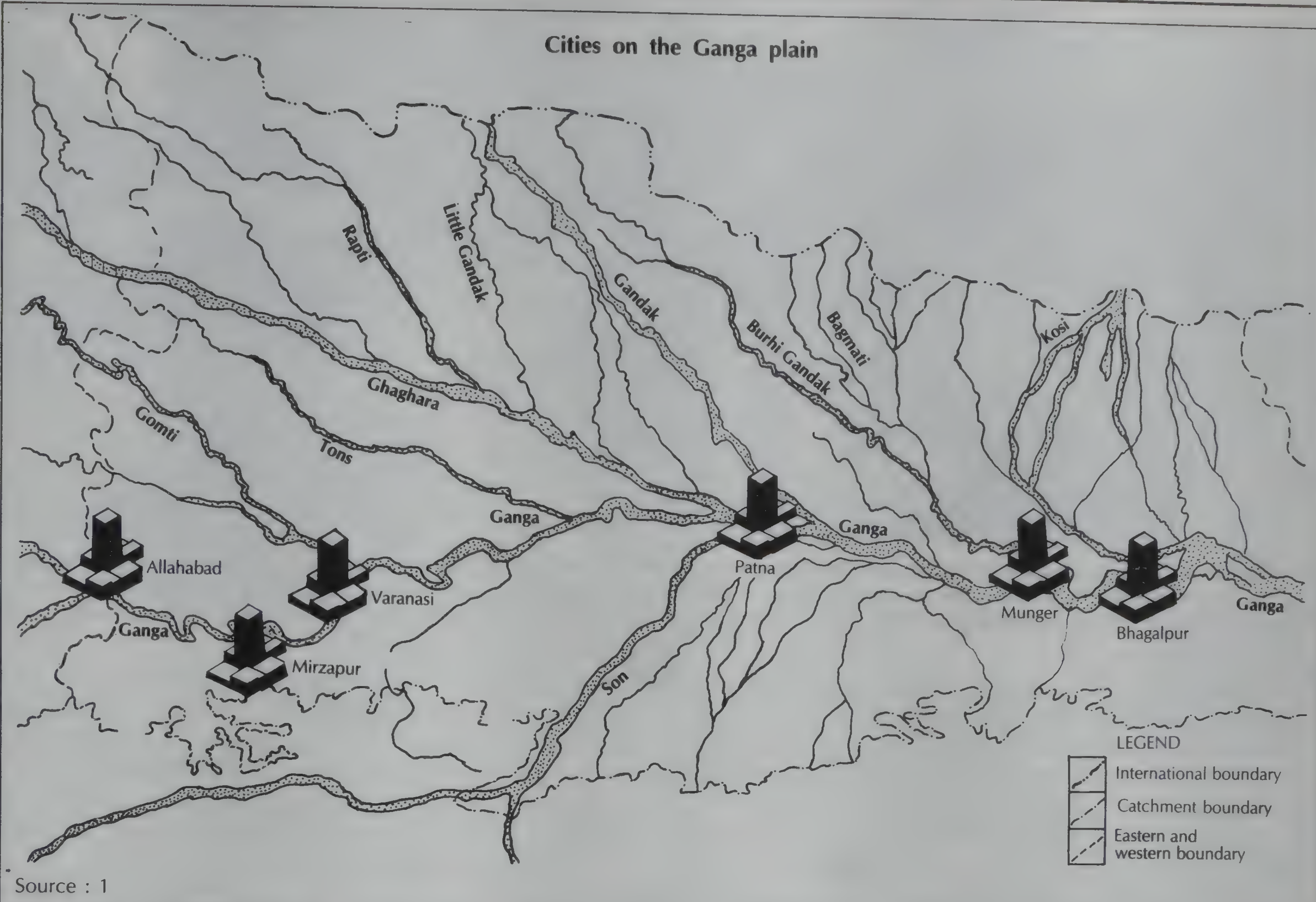
to the ecology of the flood plains of the Indus, Ganga and Brahmaputra valleys. Deforestation over the last few centuries has definitely exacerbated the flashiness of the Himalayan rivers and their silt load but they are naturally so flashy and silt laden that the increase over the natural conditions does not seem to be particularly high.

There is a tremendous paucity of scientific data but based on available knowledge and people's perceptions, two tentative conclusions can be reached. Firstly, the afforestation of the Himalayan mountains can reduce the problem of floods in the submontane plains only to a minor extent. Environmentalists should not enter into a game of one-upmanship with water engineers. There is no evidence to believe that ecological solutions like afforestation will control floods any more than engineering solutions like dams and embankments have been able to. People in the plains will have to deal with floods whether the Himalayan ranges are covered with forests. It is interesting to note that in the Assam valley it is the northern tributaries of the Brahmaputra which come down from the relatively forested slopes of Bhutan and Arunachal Pradesh that create more flood and silt problems than the southern tributaries which come down from the deforested slopes of Nagaland, Cachar hills and Meghalaya where shifting cultivation is practiced on a more extensive scale.

Secondly ecological changes that have taken place in the lowlands themselves, because of technological interventions to control floods and encroach upon the flood plains, has exacerbated the problem far more than the ecological changes in the mountainous uplands. The natural drainage system in the plains has been wilfully destroyed. Massive rivers have been embanked; drainage channels have been blocked off; and natural depressions and wetlands have been steadily encroached upon and reclaimed for agriculture. All this has not only increased the flood problem as a physical phenomenon but also, the societal susceptibility to floods.

Bad politics

By claiming that the destruction of the uplands is the cause



Unlike most North Indian rivers the Ganga is well known for its modest number of bifurcations with slow changes along its course and places of eminence which have provided favourable town sites. As a result out of the 79 riverside towns that flourished in the medieval period, 30 per cent were located along the Ganga.

a single urban centre could grow along the Kosi. Instead they have all developed as towns along its deserted channels fostered by railway lines. The westward shift of the Kosi not only devastated numerous towns within its own plain but also minimised the influence of trading centres of Muzaffarpur and Darbhanga districts.

of the growing agony in the lowlands, environmentalists are providing arguments for a very dirty kind of politics, which pits the relatively powerful people of the plains against the less powerful people of the hills. Every time there is a flood in north Bihar, the chief minister of Bihar gets an opportunity to blame Nepal. Every time there is a flood in Assam, the local leaders blame the upland tribal communities and their shifting cultivation practices in Arunachal Pradesh, Nagaland, Meghalaya, Manipur and Mizoram. And, every time there is a flood in Bangladesh, the president of Bangladesh can indulge in rhetorical politics against India. Whereas the truth is that every time there is a flood in these respective areas, these leaders should be seriously looking for changes they can make in the management of the flood plains themselves. Something they just do not wish to tackle.

The Himalayan ranges definitely need to regain their forest cover. But the reason for doing that should primarily be the needs of the hill people themselves and not the threat of floods to the distant people in the plains. Survival in the hills is not possible without a good forest cover as the hill people so well know. But if the interests of the powerful people in the plains, who control the government because of their greater population size, were to be emphasised, the result could be extremely repressive legislation like the proposal to ban shifting cultivation by law or to undertake forest conservation by throwing the people out.

Even serious institutions like the World Resources Institute in USA have been callously describing the plains people as *'hostages'* of the hill people. British environmentalist Norman Myers blames the growing population of the Himalayan people for the extensive deforestation that is taking place, a consequence of which, according to him, is the growing threat of floods in the plains. Deforestation in fact started in many parts of the Himalaya in the late 18th century gaining momentum during the 19th century as colonial governments encouraged both agricultural expansion to increase land revenue and commercial logging to promote developmental activities. Growing government control over forests alienated the people and community management systems began to break down. It would be

DEVIL AND THE DEEP : By claiming that destruction of the uplands is responsible for the agony of the lowlands weak governments have diverted attention from the ecological damage wrought in the lowlands themselves. The drainage system of the plains has been destroyed, rivers embanked, depressions reclaimed for agriculture and wetlands encroached upon. All this has not only increased the flood problem but also societal susceptibility to floods. (A.M. Gokhale)

wrong to blame the poor in the Himalaya for the deforestation that has taken place.

Government policies have had a far more devastating impact on the region's forests than the collecting of fuel and fodder by the local people. The conversion of forest land into agricultural land has not necessarily increased slope instability, surface flows or soil erosion. On the contrary, there is evidence to show that the subsistence farmer has a stabilising influence[33]. Soil loss from well managed terraces is low and, with conservation measures, it can even be reduced to levels comparable to, and even less than, forested areas. Himalayan farmers are not out to destroy the very environment they live in. Recent studies admit that mountain dwellers have a sophisticated understanding of their natural resource base and are able to manipulate them with skill. They assess and adjust to the risk of landslides, which they are also able to reclaim and repair. The biggest problem is that while villagers may often know what needs to be done, they lack the means to do it.

It is here that governments and other interventionists have failed to assist the people to help themselves. Soil conservation is definitely needed because it is beneficial for the hill farmer. Studies conducted by CSWCRTI show that soil erosion has a negative impact on crop yields. For every one cm of top soil removed, an experiment revealed that production of maize dropped 100 kg/ha in the first year, 52 kg/ha the second year, and 51 kg/ha in the third year. Soil conservation is, therefore, important to stabilise crop yields in the Himalaya[161].

Forests and grasslands supply the nutrients vitally needed to maintain crop yields. If deforestation and soil loss lead to a rapid decline in productivity, agricultural lands will be abandoned. These abandoned sites will degrade rapidly and will become responsible for high rates of sediment production through surface erosion and gully formation. Once started, gully erosion is difficult to control and can rapidly destroy terraces and other productive lands. Governments must, therefore, recognise the stabilising influence of the Himalayan farmer on the local ecology, and support the development of local agroforestry systems through people's participations. Management of forests and grasslands has remained with government agencies alienating the local villagers from their commons. Open grazing, as a result, suppresses regeneration and no effort is made by the local population to bring about self management despite a growing biomass scarcity.

Himalayan environmental degradation must be arrested and reversed but not so much for the benefit of the plains dwellers as much as for the survival and improved living standards of the hill dwellers. This, however, can only happen through participatory management and not through governmental systems that think only in terms of policing

RUBBLE ROCKED

The rain of rubble is a recent phenomenon in Badiyargad, a Himalayan village well hidden at the bottom of the Bhagirathi valley in Tehri Garhwal. Badiyargad has an irrigation channel, a new school, bus transport to Dehra Dun and Rishikesh, and a new road.

The authorities decided more or less at the same time to give the villagers a road and a water channel. There was no dispute about where to locate the channel — the villagers and the engineers were unanimous. As regards the road, the villagers suggested that the eastern side of the valley be used where probable landslips would not affect their fields and houses. But PWD engineers thought otherwise and decided to extend it on the western side, just above the main village and its fields.

Badiyargad received a new irrigation channel only to find it buried under stone and rubble, barely one season after its completion. The whole river bed was, in fact, blocked by debris from the road. Meanwhile the steady rain of rubble in Badiyargad has made walking on the village paths and fields hazardous.

The irrigation channel today adds to the statistics in the annual reports of the irrigation department. For the villagers of Badiyargad, however, it is of no avail[1].

MISERABLE RELIEF: Despair is writ large on the faces of the flood victims who wait for government relief. While flood relief for 1987 was put at Rs 80 crore — twice the amount spent on flood control for 1986-87 — very little reached the sufferers.(Krishna Murari Kishan)

THE DANGER ZONE

Experts have repeatedly recommended that the government should control human occupation of the flood plains through strong laws. A model bill was circulated by the Central government over a decade ago. But it was met by stony silence from state governments. Politicians obviously lack the will to bring any order in the humanity packed flood plains.

In July 1975, a draft bill recommending rigorous mapping of flood plains and zoning them for regulating growth of settlements and investments was drawn up on the recommendations of the ministers committee on floods and flood relief, 1972. The flood plains of India occupy some 20 per cent of its total area but are home to 30-40 per cent of its population, and with population growth this proportion is increasing. The Rashtriya Barh Ayog set up in 1976 seconded these proposals.

As pointed out by B G Verghese in *Waters of Hope*, the proposal took account of existing legislation and experience both in the country and abroad to suggest flood plain zoning as one of the most practical and effective non-structural means of reducing flood damage. The model bill dealt with preparation of flood control schemes, land use regulations, prohibition of obstructions to rivers and drains, and disaster preparedness and evacuation[1]. The Centre circulated the bill to the states but barring Manipur no other state adopted it. The Manipur Flood Plain Zoning Act came into force in 1985. It empowers the state to delineate flood prone areas and declare them off bounds for activities like permanent or temporary settlement and cultivation without prior permission. Flood prone areas have also been demarcated since then but local officials claimed in 1990 that there is "no real implementation of the law." It will require enormous political discipline to manage the flood plains properly as this is where maximum vested interests and voters live.

Even in the capital, which is the hub of planners and policy makers, a population of two million has been settled in the trans-Yamuna area of Delhi, within the active flood plain of the river. After the 1978 floods, Uttar Pradesh, Haryana and Delhi strengthened and raised many embankments along the Yamuna and closed existing gaps. According to flood experts, "the flood plain storage which helped in attenuating the 1978 flood peak will not be available now and in case such a high flood recurs, Delhi is likely to experience higher peaks." Vacant wilderness or lightly developed areas are no longer there to provide emergency flood ways. With intensive development, and valuable investments, flood losses will escalate. Another instance is of Salt Lake, a low lying area in Calcutta, which too has been reclaimed for settlement

The draft bill provided the state governments with the right to determine the use of flood plains in relation to the river. On the basis of surveys, the areas subject to flooding were to be delineated. The state government could prohibit any activity, if it went against the interest of public health and safety of property. Penalties were provided for violations and the power to remove unauthorised obstructions[2].

RBA listed three factors for the lack of enthusiasm. Firstly, there is a lack of hydrological data for different flood frequencies. Secondly, there are grave legal difficulties in enforcing land use regulation in areas of high population pressure and limited availability of land. Thirdly, an appropriate organisation and the money to meet the high costs needed to implement the programme do not exist.

As a result, every time there is a high intensity flood a hue and cry is made by politicians to make embankments to protect vulnerable investments and settlements while this money could have been used more effectively in other ways. Who cares if embankments will only make the future more difficult? Discounting the future to make the present easy is the thing that all shortsighted politicians thrive on.

natural resources. *It is not the hill dwellers who hold the population in the plains hostage, but it is the policies developed by governments in the plains that have held the people in the hills hostage.* Numerous activities can be undertaken to improve the Himalayan ecology — for example, hazard zone mapping; banning of development activities like construction, mining and roads in hazard zones; drainage control and dewatering measures; afforestation and grasslands development; and, improvement of agronomic practices[14]. But if any improvement in Himalayan ecological conditions, undertaken to improve the local subsistence economy, has an impact on reducing floods downstream in the plains, that should be treated as an incidental benefit and not the prime objective. Whether or not the erosion caused by bad road making in the Himalaya leads to the siltation of the Gangetic delta, it is of vital importance to stop making bad roads because they adversely affect local farmlands and villagers, (see box).

Living with floods

The lesson for the plains dwellers has to be the same as that for the hill dwellers — all have to learn to live within the dictates of their ecological situation. To learn to live with the risk of floods, real action must be taken in flood plains themselves. But it is here that governments have failed to take any serious action whatsoever to bring about disciplined land use. These are areas with extremely high population densities, extreme privatisation of land, extreme inequalities, intense concentration of land in the hands of a few, utter poverty and landlessness, and bitter fights and caste feuds over land. Disciplined land use and settlement policies can emerge only if determined governments can bring about a sense of fair play, undertake land reforms and involve the poor in the management of their natural resources. Environmentalists must not provide arguments for dishonest and corrupt governments to divert attention from the true issues of natural resource management in the flood plains.

It is because these governments are dishonest and weak that they cannot stop the powerful from encroaching even drainage channels and tank beds. To get votes, they do not undertake land reforms so that the poor have some chance to eke out an existence. But they take the easier option of doling out government lands, which are usually low lying land, or part of the natural drainage system. Flood plains management in India is, therefore, conspicuous by its absence.

Very few environmentalists have cared to study the flood plains. Very few voluntary agencies work in these areas as

FUTURE TALK

American water resources expert Peter Rogers, after studying the Indo-Gangetic plains concluded that the flood problem in the Ganga valley may get reduced in the future. Most environmental consequences of development are viewed as negative in their impact. But, according to Rogers, intensive irrigation in the Ganga basin may have positive benefits for the human users of the ecosystem, particularly those living in the downstream reaches.

Starting in October and November, soon after the monsoon, crops such as wheat, vegetables and rice are irrigated. At that time, rivers have plenty of water. Streams replenish groundwater aquifer along their banks. The water that seeps out in this manner leads to reduced river flows further down the basin. When the level in the rivers drops to such a level that the groundwater level is higher, the groundwater starts to flow into the rivers.

Irrigation water is pumped out by tubewells from December to May and the water levels in the rivers and in the ground decline so much that some of the tributaries cease to carry water. Groundwater is then below the bed level of the rivers. With the monsoon in early June, the rivers start to rise and the groundwater storage is also replenished.

As irrigation diversions increase, more water will evaporate, river levels will drop quicker, and larger amounts of water will flow out of the groundwater system into the rivers. In addition the increasing number of tubewells will lower the groundwater table far away from the rivers. The net effect will be to reduce the total outflow from the river basins. But during the monsoon, larger amounts of river water will seep into groundwater storages. Thus irrigation diversions will lead to a significant decline in river flows during the monsoon. Peter Rogers claims that while exact predictions are difficult, existing hydrographs do show that monsoon flows are going down. Peak flows in the Ganga plains should be affected even lower in the future as irrigation facilities spread.

Rogers' optimism, however, has to be tempered with caution. Surface irrigation systems have led to extensive waterlogging and soil salinity. Therefore, expansion of irrigation has to be viewed with caution and accompanied with good environmental management and appropriate cropping patterns. At the same time, low peak flows will not be able to flush out the silt during the monsoon. Rivers will, therefore, get increasingly clogged. And even a low flood will spill over the river's banks. Careful studies and ecologically sound plans are, therefore, vital for the survival of the Indian people inhabiting one of the world's most fertile plains.

RESPECTFUL DISTANCE: Living with floods means giving the river's flood plain due respect. Encroaching upon it can bring flood waters into the house.

compared to the gentler and relatively more equitable hill and mountain regions and unirrigated arid and semi-arid plains. Ecological problems of the flood plains and the perceptions of the local people have as, a result, rarely caught the attention of Indian environmentalists. Nature loving, middle class Indians are more likely to take a vacation in the Himalayan hill towns of Darjeeling and Mussoorie than in Darbhanga or Bhagalpur.

On their part, water resources engineers seem to suffer from a tunnel vision seeing little more than physical structures that block the flow of rivers. The National Water Policy provides for everything — sound watershed management, construction of dams, regulation of settlements through flood plain zoning, flood forecasting and continued construction of embankments[162]. But only dams and embankments get any attention at all. Most RBA recommendations relating to other measures remain on paper.

Managing the flood plains in a disciplined and environmentally sound manner is not going to be an easy task. The plains are densely populated and there is intense landlessness. Equitable solutions will be fiercely opposed. But the challenge will have to be met. Fortunately, nature has given the plains Indians an extremely robust ecosystem to live in. Human settlements have now existed in the Indo-Gangetic plains for almost four thousand years radically transforming it from what it was earlier. The plains stretching from Punjab to Bengal were once covered by primeval forests but they have all disappeared by now. This must have had a major impact on the local flora and fauna and possibly also on the local and regional climate. But the vast plains still have the capacity to support millions and millions of people and there are few signs of irreparable damage[61].

The size of the human population is, however, reaching a point that humans are now encroaching even the margins of the flood plains. The valleys of the Indus, Ganga and Brahmaputra will continue to support vast human populations but only if they are disciplined, they learn to live in harmony with the natural surroundings they have inherited, and their management systems are equitable and sustainable. We know very little about how to do this but a beginning has to be made. Knee jerk arguments either of the environmental variety or the engineering variety will not help the millions who now live in the flood plains.

Appendices

Appendix 1

Flood affected area statewise (1953-84)

	Flood affected area (mha)															
States/Years	**1953**	**1954**	**1955**	**1956**	**1957**	**1958**	**1959**	**1960**	**1961**	**1962**	**1963**	**1964**	**1965**	**1966**	**1967**	**1968**
India	5.94	7.48	11.17	8.01	4.97	6.24	4.20	7.63	6.53	6.12	3.56	4.62	1.04	4.23	7.08	8.25
Andhra Pradesh	0.07	NA	Neg	1.39	NA	0.12	0.07	Nil	0.05	0.1	0.13	0.11	NA	0.04	NA	0.07
Arunachal Pradesh	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Assam	0.08	3.15	1.41	0.60	0.40	1.25	1.04	0.47	0.19	1.62	0.58	0.76	0.6	1.78	0.26	0.41
Bihar	0.97	2.50	1.77	1.32	0.79	0.71	0.21	1.32	1.27	1.11	0.27	1.12	0.43	1.53	1.25	0.73
Goa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gujarat	NA	NA	NA	0.26	0.08	NA	1.39	0.01	0.28	0.01	0.07	0.01	Neg	Nil	NA	0.17
Haryana	Neg	Neg	0.13	0.03	Nil	0.34	0.05	0.36	0.3	0.22	0.33	0.34	0.02	0.18	0.33	0.24
Himachal Pradesh	NA	NA	NA	NA	0.23	NA	NA	NA	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Neg
Jammu & Kashmir	NA	0.05	NA	NA	0.05	NA	0.08	Nil	Nil	Nil	Nil	NA	NA	0.02	Nil	Nil
Karnataka	NA	NA	NA	NA	Neg	NA	NA	NA	0.01	0.01	Nil	0.001	0.01	NA	NA	Nil
Kerala	NA	NA	NA	0.02	0.29	NA	Nil	Nil	0.05	0.02	Nil	0.13	Neg	Nil	Nil	0.87
Madhya Pradesh	0.26	NA	0.03	0.04	0.03	Nil	0.13	Neg	NA	0.01	Nil	0.01	0.09	Nil	0.05	NA
Maharashtra	NA	NA	NA	NA	NA	0.11	0.23	Nil	0.02	0.03	0.16	0.01	NA	Nil	Nil	0.02
Manipur	Neg	NA	NA	Neg	Neg	NA	0.01	NA	Nil	0.01	Neg	0.01	Neg	0.08	Nil	Neg
Meghalaya	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mizoram	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Nagaland	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Orissa	NA	NA	0.66	0.33	Nil	0.03	1.20	1.40	1.18	Neg	0.12	NA	0.08	NA	0.76	0.99
Punjab	Neg	0.01	0.92	0.06	0.08	0.99	0.16	0.46	0.21	1.73	0.04	0.85	Neg	0.25	0.03	0.07
Rajasthan	NA	NA	NA	NA	NA	0.03	NA	0.05	0.03	0.02	0.03	0.07	0.01	0.02	0.04	0.53
Sikkim	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tamil Nadu	NA	NA	NA	Neg	0.03	NA	0.01	Neg	0.45	Nil	0.06	0.04	0.01	Nil	NA	Nil
Tripura	NA	0.01	0.01	0.03	Nil	0.04	Neg	NA	Nil	Neg	0.33	0.07	0.01	0.17	Nil	0.07
Uttar Pradesh	0.91	1.35	4.13	2.50	1.70	2.18	0.07	3.25	2.29	1.06	1.26	1.06	0.08	0.52	3.43	0.8
West Bengal	Neg	0.42	0.35	2.65	1.16	0.45	1.12	0.19	0.2	0.16	0.09	0.1	0.12	0.13	0.94	2.17

Notes: Neg: Negligible; NA: Not Available; NR: Not Reported; CD: Cyclone Damage

Source : 6

Appendix 1

Flood affected area statewise (1953-84)

States/Years	Flood affected area (mha)															
	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
India	9.54	8.45	13.25	5.72	13.72	6.7	6.15	17.89	17.43	18.61	3.98	17.08	6.46	28.11	15.98	15.22
Andhra Pradesh	1.45	0.16	Nil	0.05	N.A	0.004	0.004	1.0	5.98	0.49	0.07	0.06	0.003	0.04	2.53	3.22
Arunachal Pradesh	NA	NA	NA	NA	NA	0.00006	NR	Nil	Neg	NR	Neg	NR	Neg	Neg	Neg	NR
Assam	0.81	0.72	0.36	1.10	2.75	1.12	0.01	0.57	1.10	0.31	0.67	1.16	0.46	0.61	0.73	1.52
Bihar	0.97	0.93	4.26	0.22	0.73	3.14	2.31	2.99	1.15	2.37	0.81	1.92	1.26	0.93	1.47	2.64
Goa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Gujarat	0.04	1.03	0.01	0.02	1.05	0.01	0.6	0.63	0.94	0.26	0.48	1.32	0.23	8.50(CD)	3.04	0.45
Haryana	0.12	Neg	0.36	0.04	0.02	NR	0.07	0.7	1.0	0.71	0.01	0.16	0.03	Nil	0.48	0.06
Himachal Pradesh	Neg	NA	0.14	Neg	0.001	0.001	Neg	Neg	0.04	0.09	Neg	Neg	Neg	Nil	0.12	Nil
Jammu & Kashmir	0.01	Nil	NA	NA	0.02	NR	NA	0.03	NA	NR	NR	NR	NR	NR	0.002	NR
Karnataka	0.01	0.02	Neg	0.01	0.001	0.002	0.001	NR	Neg	0.2	0.0004	0.02	0.05	0.26	0.05	0.0014
Kerala	2.0	0.09	0.04	0.04	NA	0.3	0.02	0.01	0.67	1.10	0.21	0.06	0.09	0.0008	0.52	0.05
Madhya Pradesh	0.1	0.05	0.01	NA	1.94	0.11	Neg	5.17	NA	0.16	0.0004	NR	NR	0.43	0.07	0.03
Maharashtra	0.09	0.14	Neg	Neg	0.02	0.002	0.05	0.74	Neg	0.09	0.11	0.003	0.01	0.003	1.13	0.001
Manipur	0.01	0.06	0.01	Nil	0.002	0.01	Nil	0.02	NA	NR	NR	0.08	Nil	0.02	Nil	0.05
Meghalaya	NA	NA	NA	NA	0.01	0.02	Nil	0.001	NA	NR	NR	NR	Nil	NR	0.4	0.54
Mizoram	NR	NR	NR	NR	NR	0.000014	NR	0.00114	NA	NR	NR	NR	Nil	Nil	Nil	NR
Nagaland	NR	NR	NR	NR	Neg	NR	NA	NR	Nil	NR	NR	NR	0.0001	NR	Nil	NR
Orissa	0.65	0.32	0.61	2.97	1.34	0.19	0.51	Neg.	0.31	0.41	0.30	0.36	0.09	9.0	0.22	0.7
Punjab	0.04	0.01	0.11	0.04	0.17	Neg	0.1	0.36	0.01	0.15	0.002	0.05	0.02	Neg	0.04	0.003
Rajasthan	0.24	Nil	0.01	0.34	1.68	0.06	0.07	0.25	3.26	1.78	0.57	Nil	0.39	0.05	0.02	0.5
Sikkim	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0004	NR	NR	Nil	NR	0.02	0.02
Tamil Nadu	NA	0.01	NA	0.12	0.33	Nil	Nil	0.38	0.01	0.001	0.04	5.66	NR	0.0002	0.81	0.4
Tripura	0.08	Neg	Neg	NA	0.16	NR	0.03	0.04	0.03	0.01	Neg.	NR	0.003	0.05	0.08	1.50
Uttar Pradesh	2.40	2.91	5.26	0.31	2.63	1.35	2.18	3.63	1.30	7.34	0.7	5.86	2.99	5.50	3.86	1.69
West Bengal	0.53	2.01	2.06	0.44	0.87	0.38	0.2	1.3	1.55	3.08	0.02	0.38	0.38	0.21	0.38	1.73

Appendix 2
Surface erosion rates in the Himalaya

Source	Estimated/ measured	Area	Type of land	Soil loss (tonnes/ha/yr)
Laban 1978 quoted in Carson 1985	Estimates · (see comment 1)	Middle mountains of Nepal	Well managed forest land	5-10
			Well managed rice terraces (bunded)	5-10
			Well managed maize terraces	5-15
			Poorly managed sloping terraces	20-100
			Degraded rangeland	40-200
Carson 1985	Estimates	Nepal	Irrigated rice land	0
			Level terraces	5
			Sloping terraces	20
			Shifting cultivation	100
Carson 1985	Estimates	Watershed in Dailekh district, Middle mountains of Nepal	Undisturbed forest	5
			Scrub forest, surface protected	5
			Degraded scrub forest	15
			Irrigated bench terraces, good condition	2
			Non-irrigated bench terraces, good condition	7
			Abandoned terraces (open to grazing)	20
K G Tejwani and H N Mathur	Measured	Dehra Dun	*Average of 3 years*	
			Grass cover *(Cyonodon dactylon)*	2.1
			Natural grass	1
			Bare fallow	42.4
			Bare and ploughed fallow	155.9
	Measured	Dehra Dun	*Average of 6 years*	
			Grass cover *(Pueraria hirsuta)*	0.1
			Grass cover *(Dicanthium annulatum)*	0.2
			Grass cover *(Chrysopogon fulvus)*	0.3
			Grass cover *(Eulaliopsis binata)*	0.3
H N Mathur, Ram Babu, P. Joshie and Bakshish Singh 1976	Measured	Dehra Dun	*Small forest watershed with secondary shrub growth* (control) (average of 5 years)	0.8
			Small forest watershed	
			- before deforestation (average of 2 years)	0.4
			- year of clearfelling	0.54
			- average of two years after plantation	0.25
G Sastry and V V Dhruva Narayana 1984	Measured	Doon valley	*Agricultural watershed*	
			- Before treatment (average of 8 years)	2.4
			- After treatment (earthen bunds along field boundaries) (average of 9 years)	0.2

Continued

Appendix 2 Continued

Source	Estimated/ measured	Area	Type of land	Soil loss (tonnes/ha/yr)
			Forest watershed covered with sal trees but open to grazing	
			- Before treatment (average of 4 years)	4.7
			- After treatment (construction of brush-wood check dams) (average of 5 years)	2.8
D C Das, Y P Bali and R N Kaul 1981	Measured (sediment production rate of catch-ment result of both surface erosion and mass wasting) (Figures given in cum/ha/yr and con-verted using soil density of 1.4 t/cum)	Western Himalaya	Sutlej (Bhakra)	
			- Before soil conser-vation programme (1962)	14.47
			- After soil conser-vation programme	
			(1966)	9.13
			(1968)	8.85
			(1972)	8.51
			(1976)	8.39
			Beas (1975)	21.14
			Ramganga (1973)	24.22
			Pohru	10.79
			Giri-Bata	16.24
			Sukhna Lake (1971)	137.90
		Eastern Himalaya	Teesta	137.48
			Gumti (Tripura) (1973)	4.98
			Pagladiya (at Nalbari)	43.96
J S Singh et al	Measured	Southwestern part of central Himalaya	*Forested sites*	
			Mixed oak-pine forest	.032
			Pine forest	.025
			Oak forest (average of six sites)	.023
			Non-forested sites	
			sites damaged by landslides 6-40 years ago (average of four sites)	.056
			cropland (maize)	.064
Dhruva V V Narayana and Ram Babu 1983	Estimates	Entire Himalaya	North Himalaya, snow clad region	Neg
			North Himalaya Alpine grass and meadow region	0.16
			North Himalaya forest region 25% 75%	Nil 2.87
			Northeastern Himalaya, Alpine grass and meadow region 25% 75%	Nil 0.50
			Northeastern forest region (including Meghalaya, Nagaland etc.) 25% 50% 25% (shifting cultivation)	Nil 2.87 40.95

Continued

Appendix 2 Continued

Source	Estimated/ measured	Area	Type of land		Soil loss (tonnes/ha/yr)
CSWCRTI 1987 (p.65)	Measured	Run off plots, Dehra Dun	*Treatment*		
			Grass *(Chrysopogon fulvus)*		4.09
			Maize		19.77
			Maize + subabul		9.20
			Maize + eucalyptus		8.47
			Grass + subabul		5.74
			Subabul		1.45
			Grass + eucalyptus		1.89
			Eucalyptus		0.61
			Cultivated fallow		45.57
CSWCRTI 1987 (p.67)	Measured	Run off plots (8 per cent slope), Dehra Dun	*Treatment*		
			Average for two years		
			Maize		34.4
			Til		31.5
			Soybean		44.7
			Cowpea		28.0
			Maize + til		31.1
			Maize + soybean		31.6
			Maize + cowpea		32.1
			Cultivated fallow		90.6
CSWCRTI 1987 (p.69)	Measured	Run off plots Dehra Dun	*Treatment*		
			Average for three years		
			Zero tillage without living mulch		11.89
			Normal tillage with living Mulch		7.04
			Zero tillage with living mulch		3.27
CSWCRTI 1986, 1987 (p.98, 92)	Measured	Siwalik watershed near Chandigarh (21, 32 ha) soil conservation treatment given in 1963 and 1964	*Sediment yield*		
			Before 1956 (estimated)		Over 150.00
			1964-65 (just after treatment)		37.7
			Avg. 1965-70		12.2
			Avg. 1070-75		5.3
			Avg. 1975-80		2.1
			Avg. 1980-85		1.0
			Avg. 1985-86		0.1
			Avg. 1986-87		0.25
CSWCRTI 1986, 1987	Measured	Microwatersheds (0.8 ha to 4.5 ha) near Chandigarh, protection provided in 1978		Average 1974-76	Average 1986-87
			Annually burnt watershed changes to mixed forest	28	0.004
			Watershed with afforestation and contour trenches changes to mixed forest	1	0.0035
			Watershed with cutting of trees and shrubs and overgrazing changes to mixed forest	97	0.0035
			Overgrazed watershed changes to one with a Bhabhar grass cover	35	0.025
			Control watershed	2	0.016

Continued

Appendix 2 Continued

Source	Estimated/ measured	Area	Type of land	Soil loss (tonnes/ha/yr)	
CSWCRTI, 1986	Measured	Sukhana lake catchment, Siwalik hills near Chandigarh treatment started in early 1960s.	Cho	*Sediment yield*	
				Avg. 1958-78	Avg. 1979-85
			Kansal	11.0	10.5
			Nepli	17.3	22.5
			Ghareri	6.5	6.0
				(Assumption : Soil density 1.5 t/cum).	

Comments

1 These figures are estimates based on known sediment loads of streams. They most likely overestimate surface erosion based on the assumption that sediment production is largely a function of land use. Topsoil losses in many areas may not exceed 0.5 tons per ha per year. These estimates have probably included various forms of mass wasting in the assessment of surface erosion (Carson 1985).

Sources :

P Laban 1978, Field Measurements on Erosion and Sedimentation in Nepal, Department of Soil Conservation and Watershed Management, FAO/UNDP. IWM/SP/05.

Brian Carson 1985, *Erosion and Sedimentation Processes in the Nepalese Himalaya*, ICIMOD Occasional Paper No 1, ICIMOD, Kathmandu.

K G Tejwani and H N Mathur, Role of Grasses and Legumes in Soil Conservation, mimeo.

H N Mathur, Ram Babu, P Joshie and Bakshish Singh 1976, Effect of Clearfelling and Reforestation on Runoff and Peak Rates in Small Watersheds, *Indian Forester*, Dehra Dun, April.

G Sastry and V V Dhruva Narayana 1984, Watershed Responses to Conservation Measures, *Journal of Irrigation and Drainage Engineering*, Vol 110, No 1, March.

D C Das, Y P Bali and R N Kaul 1981, Soil Conservation Multipurpose River Valley Catchments: Problems, Programme Approach and Effectiveness, *Indian Journal of Soil Conservation*, Vol 9, No 1, April.

J S Singh, A N Pandey and P C Pathak 1983, A Hypothesis to account for the major pathway of soil loss from Himalaya, *Environment Conservation*, Switzerland, Vol. 10, No 4, Winter.

Dhruva V V Narayana and Ram Babu 1983, Estimation of Soil Erosion in India, *Journal of Irrigation and Drainage Engineering*, Vol 109, No 4, December.

CSWCRTI 1986, *Soil Conservation : Annual Report* 1986, Central Soil and Water Conservation Research and Training Institute, Dehra Dun.

CSWCRTI 1987, *Soil and Water Conservation: Annual Report 1987*, Central Soil and Water Conservation Research and Training Institute, Dehra Dun.

References

1. Gunnar Hagman 1984, *Prevention Better than Cure — Report on Human and Environmental Disasters in the Third World*, Swedish Red Cross, Stockholm and Geneva.
2. Central Water Commission 1989, *Water and Related Statistics*, CWC (Statistics Directorate), New Delhi.
3. Department of Agriculture and Cooperation 1986, *Note for Supplementaries :* Short Duration Discussion under Rule 193 in Lok Sabha on 25.11.86 regarding floods and droughts situation in the country, *mimeo.*
4. Centre for Science and Environment (CSE) 1987, *The Wrath of Nature : The impact of Environmental destruction on floods and drought*, CSE, New Delhi.
5. Rashtriya Barh Ayog 1980, *Report*, Volume 1, Ministry of Energy and Irrigation, New Delhi.
6. Central Water Commission, Statewise data on flood affected areas and damages 1953 to 1984, New Delhi, *mimeo.*
7. Ministry of Water Resources 1989, *Report of the working group on flood management for the eighth five year plan*, Government of India, New Delhi.
8. Arun Ghosh 1988, Management of Water Resources, in *Economic and Political Weekly*, October 1, Bombay.
9. R C Prasad 1975, The Landslides and Erosion problems with special reference to the Kosi Catchment, in *Proceedings of the Seminar on Landslides and Toe Erosion problems with Special reference to Himalayan Region,* Indian Society of Engineering Geology. Calcutta.
10. CBIP 1989, *Register of Large Dams in India,* Central Board of Irrigation and Power, New Delhi.
11. Norman Myers 1986, Environmental Repercussions of Deforestation in the Himalayas, in *Journal of World Forest Resource Management,* Vol 2, pp 63-72, Great Britain.
12. World Resources Institute 1985, *Tropical Forests : A Call for Action,* Part I, The Plan, World Resources Institute, Washington DC.
13. B K Subba Rao and S Francis Hilary Raj 1986, Forests and Drought : Role of Forests in Mitigation of Drought and Water Scarcity, in Seminar on Drought Management Strategies : Technical Papers, Volume I, Water Resources Development Organisation, Bangalore, May 15-16, *mimeo.*
14. K S Valdiya 1985, Accelerated Erosion and Landslide-Prone Zones in the Central Himalayan Region, in J S Singh (ed), *Environmental Regeneration in Himalaya : Concepts and Strategies*, The Central Himalayan Environment Association and Gyanodaya Prakashan, Nainital.
15. Centre for Science and Environment 1988, Annual Report *1987,* New Delhi, *mimeo.*
16. Government of India 1981, Census of India, *Report of the Expert Committee on the population Projections,* Office of the Registrar General, Ministry of Home Affairs, New Delhi.
17. Government of India, Annual estimates of population by sex and their exponential rates of growth (per cent) 1901 to 1981, Office of the Registrar General, Ministry of Home Affairs, New Delhi, *mimeo.*
18. K P Sundaram (ed) 1989, *Fertiliser Statistics (1988-89),* Fertiliser Association of India, New Delhi.
19. Government of India 1988, *First Report of the Ninth Finance Commission (for 1989-90),* Ministry of Finance, New Delhi, 1989.
20. C Prasad and V K Verma, Slope Failure : A Case Study in the Catchment Areas of Alaknanda and Bhagirathi Rivers, *mimeo.*
21. O N Dhar, A K Kulkarni and P R Rakhecha 1986, Meteorology of Heavy Rainfall over the Garhwal-Kumaon Region of the Himalayas : A Brief Appraisal, in *Proceedings of Workshop on Flood Estimation in Himalayan Region,* Central Board of Irrigation and Power, New Delhi.
22. V S Krishnaswamy and M S Jain 1975, A Review of some of the major landslides in northern and north western Himalayas in *Proceedings of the Seminar on Landslides and Toe Erosion Problems with special reference to Himalayan region,* Indian Society of Engineering Geology, Calcutta.
23. E V Narayanan 1975, Hurdles on Himalayan Highways, in *ibid.*
24. P B Saxena 1987, *A Modern Approach in Geography for the evaluation of soils and landform systems of land use planning in Himalayan Ecosystem of the Alaknanda Basin (Garhwal Himalaya),* Concept Publishing Company, New Delhi.
25. Indian National Science Academy, An Interim Report on the Alaknanda Flash Floods, *mimeo.*
26. E T Atkinson 1981, *The Himalayan Gazetteer,* Volume III, Parts I and II, Cosmo Publications, New Delhi.
27. R K Bhandari and Chanchal Gupta 1985, Problems of Landslides in the Himalaya and Future Directions, in J S Singh (ed.), *op.cit.*
28. Indian National Science Academy, A proposal for the constitution of a Study Team under the auspices of the INSA to make an on the spot investigation of the recent flash flood in Alaknanda, *mimeo.*
29. Indian National Science Academy, Note Indicating causes leading to abnormal floods in Alaknanda near Belakuchi and the general flood situation in the valley, *mimeo.*
30. R A Chansarkar 1975, Geologic and geomorphic factors in landslides investigations, in *Proceeding of the Seminar on Landslides and Toe Erosion Problems with special reference to Himalayan Region, op.cit.*
31. C P Bhatt 1978, *Himalaya Ki Chetavani,* in *Dinman,* New Delhi, 17-23 September.
32. S R Pradhan, Role of Landslides in the Planning and Execution of Lagyap Hydel Project, Sikkim : A Case History, *mimeo.*
33. Jack D Ives and Bruno Messerli 1989, *The Himalayan Dilemma: Reconciling Development and Conservation,* United Nations University and Routledge, London and New York.
34. J S Soin, Landslide problems on roads in Sikkim and north Bengal, and measures adopted to control them, *mimeo*
35. S Raghuraman 1975, Hydrology and its contribution to landslides with special reference to problems in Sikkim, in *Proceedings of Seminar on Landslides and Toe Erosion Problems with special reference to Himalayan Region, op.cit.*
36. R K Bhandari, Landslides in Himalaya — Problems, Causes and Cures, *mimeo*
37. Harish Chandra 1975, Landslides in Teesta Valley, in *Proceedings of Seminar on Landslides and Toe Erosion Problems with Special Reference to Himalayan Region, op.cit*
38. A Dasgupta and S K Roy 1986, Estimation of Design Flood for Teesta Dam, in *Proceedings of Workshop on Flood Estimation in Himalayan Region, op.cit.*
39. D S N Ayyar 1975, Landslides, a hold up on the Highway — its impact

on society, in *Proceedings of Seminar on Landslides and Toe Erosion Problems with Special Reference to Himalayan Region. op.cit.*

40. T K Natrajan, R K Bhandari, D S Tolia and A V S R Murty, Some Case records of Landslides in Sikkim, *mimeo*

41. B N Sinha, S N Chaturvedi and P N Verma 1975, A Geological Study of Birik Slide and its possible solutions, in *Proceedings of Seminar on Landslides and Toe Erosion Problems with Special Reference to Himalayan Region. op.cit.*

42. Centre for Science and Environment 1987, *The Wrath of Nature : The Impact of Environmental Destruction on Floods and Droughts,* CSE, New Delhi.

43. S L Shah, Watershed Management in Uttarakhand, *mimeo.*

44. R K Bhandari 1977, Some Typical Landslides in the Himalaya, in Proceedings of the 2nd International Symposium on Landslides, *mimeo.*

45. T K Natarajan and P J Rao, Engineering Properties of the Sivalik Clay Shales of India, *mimeo*

46. Nigel Harris 1989, Tibet : Continents in Collision, *New Scientist,* London, 9 December.

47. John F Shroder Jr 1989, Hazards of the Himalaya, *American Scientist* Vol 77, November-December.

48. Y P Rao 1978, The Himalayas : Their Climate, in *Proceedings of the National Seminar on Resources, Development and Environment in the Himalayan Region,* National Committee on Environmental Planning and Coordination, New Delhi.

49. S D S Abdi 1986, Flood Estimation in Himalayan Catchment, in Anonymous, *Proceedings of Workshop on Flood Estimation in Himalayan Region, op.cit*

50. V K Jain, H C Bhatia and M S Alam 1986, Design Flood Estimation for Lakhwar Dam, *ibid.*

51. O N Dhar and B K Bhattacharya 1976, Variation of rainfall with elevation in the Himalayas — a pilot study, in *Indian Journal of Power and River Valley Development,* June.

52. O N Dhar, B N Mandal and A K Kulkarni 1982, Effect of Pir Panjal Range of Himalayas over Monsoon Rainfall Distribution in Kashmir Valley, *mimeo.*

52a. O N Dhar, B N Mandal and A K Kulkarni 1982, A Study of Heavy Rainfall over the Ganga Basin up to Hardwar, *mimeo.*

53. Pritam Singh, A S Ramanathan and V G Ghanekar, Flash Floods in India, *mimeo.*

54. O N Dhar and J Narayanan 1965, A Brief Study of Rainfall and Flood Producing Rain Storms in the Beas Catchment (up to Pong), in *Indian Journal of Meteorology and Geophysics,* Vol 16, No 1, January.

55. O N Dhar, and M K Soman and S S Mulye 1984, Rainfall over the Southern Slopes of the Himalayas and the adjoining plains during 'breaks' in the monsoon, in *Journal of Climatology,* Vol 4, p 671-676.

56. Jagdish Bahadur 1985, Role of Snow and Glacier Melt Contributions for Environmental Regeneration in the Himalayas, in J S Singh (ed), *Environmental Regeneration in Himalaya : Concepts and Strategies, op.cit.*

57. K N Sharma and E Divatia 1986, Flood Estimation for Dhauliganga H E Project, in *Proceedings of Workshop on Flood Estimation in Himalayan Region, op.cit.*

58. Inger-Marie Bjonness 1986, Mountain Hazard Perception and Risk avoiding Strategies among the Sherpas of Khumbu Himal, Nepal, in *Mountain Research and Development,* International Mountain Society and United Nations University, Colorado, Vol 6, No 4, November.

59. C K Sharma 1987, The Problem of Sediment Load in the Development of Water Resources in Nepal, in *Mountain Research and Development,* Vol 7, No 3, August, *ibid.*

60. Brian Carson 1985, *Erosion and Sedimentation Processes in the Nepalese Himalaya,* ICIMOD, Kathmandu.

61. Peter Rogers 1989, History of Ganges Water Resources with an eye to the future, in *Development Ecology,* Patna, Vol II, No 1, April.

62. M I Jain and J C Basur 1986, Hydrometeorological observations during operation and maintenance stage of Pong reservoir, in *Proceedings of workshop on flood estimation in Himalayan region, op.cit.*

63. J S Singh, A N Pandey and P C Pathak 1983, A Hypothesis to Account for the Major Pathway of Soil Loss from Himalaya, in *Environmental Conservation,* Vol 10, No 4, Geneva.

64. D A Gilmour, M Bonnell and D S Cassells 1987, The Effects of Forestation on Soil Hydraulic Properties in the Middle Hills of Nepal : A Preliminary Assessment, *Mountain Research and Development,* Vol 7, No 3, August, *op.cit*

65. John J Metz 1989, Himalayan Political Economy : More Myths in the Closet? in *Mountain Research and Development,* Vol 9, No 2, *op.cit.*

66. J D Milliman 1981, Transfer of River-borne Particulate Material to the Oceans, in *River Inputs to Ocean Systems,* United Nations Environment Programme, New York.

67. K G Tejwani and H N Mathur, Role of Grasses and Legumes in Soil Conservation, *mimeo.*

68. Dhruva V V Narayana and Ram Babu 1983, Estimation of Soil Erosion in India, in *Journal of Irrigation and Drainage Engineering,* Vol 109, No 4, December.

69. N Majumdar, Distribution and Intensity of Landslide Processes in North-Eastern India — A Zonation Map Thereof, *mimeo.*

70. Satish Chandra and V K Lohani 1985-86, *Forest Influences on hydrological Parameters,* National Institute of Hydrology, Roorkee.

71. Lawrence S Hamilton, Targets and Non-Targets for Action by World Bank in Watershed Management and Rehabilitation, *mimeo.*

72. H N Mathur, Ram Babu, P Joshie and Bakhshish Singh 1976, Effect of clearfelling and Reforestation on Runoff and Peak Rates in Small Watersheds, *Indian Forester,* Dehra Dun, April.

73. Gunturi Sastry and V V Dhruva Narayana 1984, Watershed Responses to Conservation Measures, in *Journal of Irrigation and Drainage Engineering,* Vol 110, No 1, March.

74. H M Gregersen, K N Brooks, J A Dixon and L S Hamilton 1988, *Guidelines for economic appraisal of watershed management projects,* FAO, Rome.

75. V V Dhruva Narayana 1987, Downstream Impacts of Soil Conservation in the Himalayan region, in *Mountain Research and Development,* Volume 7, No 3, August, *op.cit.*

76. Lawrence S Hamilton 1987, What are the Impacts of Himalayan Deforestation on the Ganges-Brahmaputra Lowlands and Delta? Assumption and Facts, in *Mountain Research and Development,* Vol 7, No 3, August, *op.cit.*

77. William James H Ramsay 1986, Erosion problems in the Nepal Himalaya: An Overview, in S C Joshi (ed), *Nepal Himalaya: Geo-Ecological Perspectives,* Himalayan Research Group, Nainital.

78. R B Bansode and S R Pradhan 1975, Landslides in Nepal Himalaya and their influence on the Kosi dam, in *Proceeding of the Seminar on Landslides and Toe Erosion problems with special reference to the Himalayan region, op. cit.*

79. D C Goswami 1985, Brahmaputra River, Assam, India : Physiography, Basin denudation, and channel aggradation, in *Water Resources Research,* Vol 21, No 7, p 959-978, July.

80. V P Singh 1989,'I Believe', in *The Illustrated Weekly of India,* Bombay, August 20.

81. Martin J Haigh, Jivan S Rawat and Sukesh K Bartarya 1989, Environmental indicators of Landslides Activity along the Kilbury Road (Nainital, Kumaon, Lesser Himalaya), in *Mountain Research and Development,* Vol 9, No 1, February, *op. cit.*

82. K G Tejwani 1987, Sedimentation of Reservoirs in the Himalayan Region, India, in *Mountain Research and Development,* Vol 7, No 3, August, *op. cit.*

83. Indian Society of Engineering Geology (ISEC) 1975, *Proceedings of Seminar on Landslides and Toe Erosion Problems with Special Reference to Himalayan Region, op.cit.*

84. Debjani Sinha 1989, On the Waterfront, in *Sunday,* Calcutta, May 25.

85. D C Das, Y P Bali and R N Kaul 1981, Soil Conservation in Multipurpose River Valley Catchments: Problems, Programme Approach and Effectiveness, *Indian Journal of Soil Conservation,* Vol 9, No 1, April.

86. John N Holeman 1968, The Sediment Yield of Major Rivers of the World, *Water Resources Research;* Vol 4, No 4, August.

87. James M Coleman 1969, Brahmaputra River: Channel Processes and Sedimentation, *Sedimentary Geology,* Vol 3, No 2/3, Elsevier Publishing Company, Amsterdam.

88. CSWCRTI, *Annual Report 1981,* Dehra Dun.

89. Anon 1988-89, *Fertiliser and Allied Agriculture Statistics 1988-89 : Northern Region,* Fertiliser Association of India, New Delhi.

89a. Anon 1985-86, *District Annual Plan in Agriculture for Darjeeling 1985-86,* Principal Agriculture officer, Darjeeling.

89b. Anon 1988, *Basic Road Statistics of India 1983-84,* Ministry of Surface Transport, New Delhi.

89c. Anon 1985, *The Report of the Working Group on Hill Area Development Programme for the Seventh Five Year Plan 1985-90,* Planning Commission, New Delhi.

90. G Venkataramani 1987, A River of Sorrow, in *Frontline,* Madras, December.

91. D N Borthakur 1981, Strategy of Agricultural Production in Flood Prone Areas with special reference to the Brahmaputra Valley, in Proceedings of International Conference on Flood Disasters, December 3-5 1981, New Delhi. *Mimeo.*

92. D C Goswami 1989, Floods and their impact on the Agriculture of Assam, *mimeo.*

93. Anon 1987, *Report of the Expert Committee on 1986 Floods in Assam,* Government of Assam, Guwahati.

94. Romesh Bhattacharji 1989, Down the Big River, in *Frontline,* Madras, September 2-15.

95. Anon 1988, Flood Relief : PM Plays Dirty, in *Deccan Herald,* Bangalore, September 21.

96. Anon 1987, Two million affected : rivers recede, in *The Sentinel,* Guwahati, August 19.

97. Anon 1987, Centre's Attitude Towards Assam Flayed, in *The Sentinel,* Guwahati, August 23.

98. Anon 1987, 20 crore adhoc Central Relief for Assam, in *Deccan Herald,* Bangalore, August 27.

99. Anon 1987, Flood of Misery in Brahmaputra Basin, in *Patriot,* Calcutta, August 22.

100. Anon 1988, State Diverting Funds : PM Sanctions Rs 40 crore for Flood Relief, in *The Sentinel,* Guwahati, September 15.

101. Anon 1988, PM Plays Dirty, Says Mahanta, in *The Telegraph,* Calcutta, September 20.

102. Anon 1988, Assam MPs Demand Flood Control Steps, in *The Sentinel,* Guwahati, August 11.

103. D C Goswami 1988, Estimation of Bedload Transport in the Brahmaputra River (Assam), in *Indian Journal of Earth Sciences,* Vol 15, No 1.

104. A K Nag 1988, Earthquakes have changed river course, in *Amrita Bazaar Patrika,* Calcutta, August 19.

105. Anon, A Short Note on the Flood Problem of Assam, *mimeo.*

106. M S Prabhakara 1989, Brahmaputra Billows on, in *Frontline,* Madras, September 2-15.

107. B C Allen, E A Gait, C G H Allen and H F Howard 1984, *Gazetteer of Bengal and North-East India,* Mittal Publications, New Delhi.

108. M M Das 1984, *Peasant Agriculture in Assam,* Inter India Publications, New Delhi.

109. Sachin Barooah 1988, Flood Devastates Rural Economy, in *The Hindustan Times,* New Delhi, July 22.

110. D C Goswami and P Sharma 1988, Waterlogged Lands in Naogong District, Assam : A Study in Environmental Geomorphology, *mimeo.*

111. Abhik Gupta 1989, Water pollution in Barak Valley, Assam, JFS-88 Report, Centre for Science and Environment, New Delhi, *mimeo.*

111a. B G Verghese 1990, *Waters of Hope : Himalaya-Ganga Development and Cooperation for a billion people,* Oxford and IBH Publishing Co, New Delhi.

112. Anon 1989, Rehabilitation of Flood Victims may displace original inhabitants, in *The Sentinel,* Guwahati, July 24.

113. S Deb Roy 1989, Mutilated Face of Nature and the future of man, *mimeo.*

114. R Mohan 1989, AGP Concerned Over Centre's Reluctance, in *Patriot,* Calcutta, August 14.

115. Anon 1989, Concern at Centre's Attitude to Floods in State, in *The Sentinel,* Guwahati, June 30.

116. T N Barman 1989, Channel Dredging in the Brahmaputra River System and Environmental Effect, *mimeo.*

117. Anon, A note on Subansiri and Dihang Dam project, *mimeo.*

118. Anon 1987, PM Bestows Rs 20 crore, in *The Sentinel,* Guwahati, August 26.

119. Santanu Ghose 1989, Floods Destroy Crops Worth Rs 67 crore, in *The Telegraph,* Calcutta, August 17.

120. Anon 1989, Flood Control Scheme for Barak Valley, in *The Sentinel,* Guwahati, May 1.

121. S D Phukan 1987, Assam Floods Deluge and Disaster, in *The Times of India,* New Delhi, August 22.

121a. S N Phukan 1988, An Approach to Flood Control in the Brahmaputra Valley — I, in *The Sentinel,* Guwahati, September 3.

122. G S Jakhade, A S Murty and S Sethurathinam 1984, Frequency Floods in Brahmaputra Valley - Regional Flood Frequency Approach, in *Irrigation and Power,* January.

123. Anon, A note on flood and erosion problem in Brahmaputra Valley and its management, *mimeo.*

124. Bindeshwari Singh 1988, River Embankments of no avail, in *Indian Express,* New Delhi, June 3.

125. Anon 1988, Uncertain Course of Rivers Worries Bihar Planners, in *The Financial Express,* New Delhi, April 26.

126. Government of Bihar 1987, *Memorandum on Floods in Bihar: July and August 1987,* Relief and Rehabilitation Department, Patna.

127. Anon 1987, Letter of Dr Jagannath Mishra to the Prime Minister Rajiv Gandhi, in *The Telegraph,* Calcutta, August 26.

128. Kuldip Nayar 1987, Thousands in Bihar Face Death, in *The Tribune,* Chandigarh, November 22.

129. Government of India 1978, *Report of the Working Group on Integrated Action Plan for Flood Control (in Indo-Gangetic Basin),* Ministry of Agriculture and Irrigation, New Delhi, December.

130. P C Roy Choudhary 1963, *Bihar District Gazetteers : Purnea,* Superintendent Secretariat Press, Patna; L S S O'Malley 1911, *Bengal District Gazetteers: Purnea,* Bengal Secretariat Book Depot, Calcutta.

131. Bhogendra Jha 1985, *River Management of Flood, Drought and Power Shortage in Bihar,* Janashakti Printing Press, Patna.

132. P C Roy Choudhary 1965, *Bihar District Gazetteers : Saharsa,* Superintendent Secretariat Press, Patna.

133. Government of Bihar 1987, *Draft Annual Plan 1988-89 : Irrigation and Flood Control,* Water Resources Development and Flood Control Department, Patna, December.

134. Farzand Ahmed 1982, The Bagmati Blunder, in *India Today,* New Delhi, December 15.

135. P C Roy Choudhary 1958, *Bihar District Gazetteers : Muzaffarpur,* Superintendent Secretariat Press, Patna.

136. Anon 1987, *Hindustan,* October 10, Patna.

137. CWC 1982, *The Kosi River: Its Morphology and Mechanics in*

Retrospect and Prospect, Vol I, Central Water Commission, New Delhi, April.

138. Anon 1987, Calamity Compounded by Human Negligence, in *The Hindu,* August 23.

139. Saryu Rai 1988, personal communication.

140. Anon 1988, *Hindustan,* Patna.

141. C C Patel, State and National Policies and International Cooperation, Keynote paper, Secretary, Ministry of Irrigation, Government of India, *mimeo.*

142. O N Dhar and J Narayanan, A Study of Rainspell Associated with the Unprecedented Flood in the Kosi River in August 1954, *mimeo.*

143. S Dasgupta and N C Ghose 1987, Geology and Groundwater Resources of north Bihar, in K C Sahu (ed) *Role of Earth Sciences in Environment,* National Symposium, IIT, Bombay, December.

144. M C Chaturvedi 1981, Flood Management : New Concepts, Technology and Planning, in *International Conference on Flood Disasters : Proceedings,* Indian National Science Academy, New Delhi, December 3-5, 1981.

145. Subrata Sinha, Problems and Prospects of Flood Control in Eastern India, *mimeo.*

146. S B Synghal 1983, in *The Statesman,* Delhi, September 30.

147. G S Bhalla and D S Tyagi 1989, *Patterns in Indian Agricultural Development: A District Level Study,* Institute for Studies in Industrial Development, New Delhi.

147a. P Rogers and T Prasad 1988, Flood Control and Rural Development in Eastern India, paper for the National Workshop on Technology Delivery System for Rural Development, October 13-15, *mimeo.*

148. T Prasad and V S Prasad 1988, Groundwater Quality Investigations in Bagmati Command Area, National Seminar on Management of Water Waste Water Systems, February 27-28, *mimeo.*

149. Arvind N Das 1987, Bihar Society in Perspective, in A N Sharma and S Gupta (ed), *Bihar Stagnation or Growth,* Spectrum Publishing House, Patna.

150. Anon 1987, The Deluge, in *The Times of India,* Delhi, August 28.

151. K R Krishna Gandhi 1981, Politics of flood relief vs flood control, in *Economic and Political Weekly,* Bombay, November 21.

152. Anon, 1987, Working paper and Abstract of papers : Workshop on problems of Gangetic Diara of Eastern Bihar, Centre for Regional Studies, Bhagalpur University, Bhagalpur, *mimeo.*

153. K N Singh and Kartar Singh 1988, *Bihar Rajya me Munger jile ke diara kshetra ka krishi utpadan badhane me badhak samasyayen — ek adhyayan,* Indian Agricultural Research Institute, New Delhi.

154. Mohan Prasad 1990, *Ganga ke garbh se nikle bhukhandon par bahta hai khoon,* in *Dinman Times,* New Delhi, May 6-12.

155. Mukul Sharma 1988, *Bihar ka Diara kshetra,* Shahid Bhagatsingh Research Samiti, Ludhiana.

156. Arun Sinha 1990, Bhagalpur Blindings: 10 years After, in *The Illustrated Weekly of India,* Bombay, April 1.

157. Nirmal 1984, *Ganga me tairti Piparia ki lashen,* in *Gandhi Marg,* Gandhi Peace Foundation, New Delhi, April.

158. Nirmal 1985, *To phir Taufir Diara ki lashen Ganga Maiya ko samarpit,* in *Gandhi Marg,* Gandhi Peace Foundation, New Delhi, November.

159. ICAR 1987, Annual Progress Report 1985-86, All India Coordinated Research Project for Diara Land Improvement, Bhagalpur, *mimeo.*

160. ICAR 1983, Annual Progress Report 1981-83, All India Coordinated Research Project for Diara Land Improvement, New Delhi, *mimeo.*

161. K G Tejwani and Ram Babu 1982, Economic evaluation of the environmental benefits of soil and water conservation programmes, in *Indian Journal of Soil Conservation,* Vol 10, No 2-3, cited in H M Gregersen, K N Brooks, J A Dixon and L S Hamilton 1988, *Guidelines for economic appraisal of watershed management projects,* FAO, Rome.

162. Ministry of Water Resources 1986, National Water Policy (draft), New Delhi.

163. A C Goswami 1972, Regional flood frequency analysis of Brahmaputra basin in North east India, in IE(I) *Journal-CI,* Vol 52.

164. K L Rao 1979, *India's water wealth,* Orient Longman Ltd. New Delhi.

164. Govt. of India 1986 *Indian Standard Criteria for earthquake resistant design of structures,* Indian Standards Institution, New Delhi, Fourth Revision.

Embankment ills

1. Rashtriya Barh Ayog 1980, *Report,* Vol 1, Ministry of Energy and Irrigation, New Delhi.

Tall blunders

1. Vijay 1988, Man-made Disaster, *Punjab Kesari,* Jalandhar, October 5.
2. Anon 1988, BBMB Chairman gunned down by terrorists, *Newstime,* Hyderabad, November 8.
3. Bharat Dogra 1986, The Nature of Annual Inundations, in PCP, October 23-25.
4. Centre for Science and Environment 1985, *State of India's Environment 1984-85 : Second Citizens' Report,* New Delhi.
5. Subrata Sinha, West Bengal Floods : Background and Perspective, *mimeo.*
6. Sulabha Brahme and Prakash Gole 1967, *Deluge in Poona,* Asia Publishing House, Poona.
7. H J Karia and P P Oza 1982, Catastrophe of Dam Burst at Morvi (Gujarat) and Restoration of Water Supply System, in *Journal of the IWWA,* April-June 1982.
8. Anon 1982, Karnataka : Natural Calamity that was not, in *Link,* New Delhi, January 31.
9. Raj Chengappa 1981, Village turns graveyard, in *India Today,* New Delhi, November 15.
10. Ministry of Water Resources 1990, *Reply to unstarred question No 1339 in Lok Sabha by Shrimati Basava Rajeswari,* March 21.
11. Vijay Paranjpye 1987, Tehri, in *Sanctuary,* Bombay, Vol VII, No 4, October-December.

Hirakud's tale

1. Sadhana Satapathy 1989, Floods and Flood Control Policies: An Analysis with Reference to the Mahanadi Delta in Orissa, paper presented at the workshop on Traditional Technologies in Indian Agriculture, National Institute of Science Technology and Development Studies, New Delhi, March 6-8, *mimeo.*

Flash flood

1. J M Girglani 1980, Flash floods in Vamsadhara river, Srikakulam District (Andhra Pradesh) — A case study, Paper prepared for presentation to the International conference on Flood Disasters, Indian National Science Academy, New Delhi, December 3-5 1981, *mimeo.*
2. E Amminedu 1984, Environmental Impact of floods-Regional analysis of Vamsadhara river basin, Ph.D thesis submitted to the Andhra University, Visakhapatnam, *mimeo.*

Rains of terror

1. O N Dhar, A K Kulkarni and P R Rakhecha 1986, Meteorology of Heavy Rainfall over the Garhwal-Kumaon Region of the Himalayas, *Proceedings of Workshop on Flood Estimation in Himalayan Region* Central Board of Irrigation and Power, New Delhi.
2. O N Dhar 1962, A Study of rainfall and floods in the Yamuna catchment (up to Delhi), *Indian Journal of Meteorology and Geophysics,* Vol. 13, No 3.
3. O N Dhar, B N Mandal and A K Kulkarni 1982, A Study of Heavy Rainfall over the Ganga Basin up to Hardwar, in *Proceedings of International Symposium on Hydrological Aspects of Mountainous Watersheds,* Roorkee University, Roorkee.

Yamuna's wrath

1. O N Dhar, A Study of Rainfall and Floods in the Yamuna Catchment (up to Delhi), *Indian Journal of Meteorology and Geophysics*, Vol 13, No 3.

Nepal's nightmare

1. D Vuichard and M Zimmermann 1986, The Langmoche Flash Flood (Khumbu Himal, Nepal), in *Mountain Research and development*, University of Boulder Colorado, Vol 6, No 1, February.
2. D Vuichard and M Zimmermann 1987, The 1985 Catastrophic Drainage Of A Moraine-Dammed Lake (Khumbu Himal, Nepal) : Cause And Consequences, in *Mountain Research and Development*, Vol 7, No 2, *op cit*.

Stablising slopes

1. Robert F Schroeder 1985, Himalayan Subsistence Systems: Indigenous Agriculture in Rural Nepal, in *Mountain Research and Development*, Vol 5, No 1, op cit.
2. Kirsten Johnson, Elizabeth Ann Olson and Sumitra Manandhar 1982, Environmental Knowledge and Response to Natural Hazards in Mountainous Nepal, in *Mountain Research and Development*, Vol 2, No 2, *op cit*.
3. Sumitra M Gurung 1989, Human Perception of Mountain Hazards in the Kakani-Kathmandu Area: Experiences From the Middle Mountains of Nepal, in *Mountain Research and Development*, United Nations University, Davis, California, Volume 9, No 4.

Roving rivers

1. Debjani Sinha 1989, On the Waterfront, in *Sunday*, Calcutta, May 25.
2. James M Coleman 1969, Brahmaputra River: Channel Processes and Sedimentation, in *Sedimentary Geology*, Vol 3, No 2/3, Elsevier Publishing Company, Amsterdam.

Terrible tremors

1. B G Verghese 1990, *Waters of Hope: Himalaya-Ganga Development and Cooperation for a billion people*, Oxford and IBH Publishing Co., New Delhi.
2. D C Goswami 1985, Brahmaputra River, Assam, India: Physiography, Basin denudation and channel aggradation, in *Water Resources Research*, Vol 21, No 7, p 959-978, July.

Shrinking isle

1. G Venkataramani 1987, On the Battered Banks, in *Frontline*, Madras, December 26 to January 8.
2. M S Prabhakara 1989, Brahmaputra Billows on, in *Frontline*, Madras, September 2-15.

Unsafe sanctuary

1. James A Wolstencroft, S A Hussain and C K Varshney, India, in *A Directory of Asian Wetlands*, IUCN, Gland.
2. Utpal Bordolio 1988, Assam floods endanger Kaziranga park rhinos, in *Deccan Herald*, Bangalore, October 16.
3. Anon 1988, Contingency plan to save Kaziranga prepared, in *The Sentinel*, Guwahati, December 31.

Swamped issues

1. M S Prabhakara 1990, Caught in a quagmire, in *Frontline*, Madras, June 23-July 6.
2. Ankur Barbora 1989, Deepar bil: Towards extinction?, in *The Sentinel*, Guwahati, June 10.
3. PTI 1989, INSTER up in arms against proposed railway line, in *The Sentinel*, Guwahati, December 3.
4. Anon 1989, Abandonment of NFR line through Deepar bil sought, in *The Sentinel*, Guwahati, June 11.
5. Anon 1989, Rail plan threat to sanctuary, in *Indian Express*, New Delhi, June 13.

Barak's fury

1. Jyoti Lal Choudhury 1989, The deluge and disaster in Barak valley, in *The Sentinel*, Guwahati, August 12.
2. D C Goswami 1989, floods and their impact on the agriculture of Assam, *mimeo*.
3. Santanu Ghosh 1989, Floods destroy crops worth Rs 67 crore, in *The Telegraph*, Calcutta, August 17.
4. Anon 1989, State flood toll rises to 22, in *The Sentinel*, Guwahati, August 18.

Grand failure

1. CWC 1982, *The Kosi River : Its Morphology and Mechanics, in Retrospect and Prospect*, Vol 1, Central Water Commission, New Delhi, April.
2. Nirmal Sengupta 1987, Politics and Eclectics of Irrigation, in A N Sharma and S Gupta (ed), *Bihar: Stagnation and Growth*, Spectrum Publishing House, Patna-3. L S S O'Malley 1911, *Bengal District Gazetteers* : Purnea, Bengal Secretariat Book Depot, Calcutta.

Wetland status

1. James A Wolstencroft, S A Hussain and C K Varshney, *India in A Directory of Asian Wetlands*, IUCN, Gland.
2. E Sai Kumar Reddy 1990, Environmental impact assessment of Inchampalli multipurpose river valley project across river Godavari (Andhra Pradesh). Centre for Environmental Planning and Technology, Ahmedabad, *mimeo*.

Deep water problems

1. Ajay Kumar, K C John and S Sharan 1990, Sustainable Agricultural Development in Chaur: Linkages among policies, Transactions and Ecological risk, Paper presented at an Agricultural Workshop, March 6-9, *mimeo*.

Inglorious fate

1. R D Oldham 1901, Notes on the geology of Son valley, Memoir of the Geological Survey of India, vol XXXI in Ganga Prasad Jha 1989, *Agriculture in flood prone regions*, Inter-India Publications, New Delhi.
2. J A Dunn 1942, Memoir of the Geological Survey of India, vol LXXVIII, in Ganga Prasad Jha 1989, *Agriculture in flood prone regions*, Inter-India Publications, New Delhi.
3. Ganga Prasad Jha 1989, *Agriculture in flood prone regions*, Inter-India Publications, New Delhi.

Major setback

1. R K Mukherjee 1990, personal communication, New Delhi.
2. RBA 1980, *Rashtriya Barh Ayog: Report*, Volume II (Appendices), Ministry of Energy and Irrigation, New Delhi.
3. Subrata Sinha, West Bengal Flood Control: Case for Development by Conservation, *mimeo*.
4. Kapil Bhattacharya, *Bangladesher Nod, Nodi O Porikolpona*, Bidyesoy Library, Calcutta, quoted in Dunu Roy 1985, Politics of Environment, *The State of India's Environment 1984-85*, Centre for Science and Environment, New Delhi.

Malda's misery

1. Bireswar Banerji 1985, Genesis of Floods in West Bengal and their impact on Society, in *The Deccan Geographer*, Vol 23, No 1, January to June, pp 40-54.
2. Sumantrao Mukherji 1979, Floods in West Bengal, M Phil dissertation, Jawaharlal Nehru University, New Delhi, *mimeo*.

Watery prison

1. Raghupati 1989, Report of the Padyatra in Saharsa District, *mimeo*

Meerut's khadars

1. C Mumtamayee 1989, *Rural Ecology,* Ashish Publishing House, New Delhi.

Ganga's dance

1. Chandi Prasad Bhatt 1987, *The Ganga Yatra,* Dasholi Gram Swarajya Mandal, Gopeshwar, *mimeo.*

Endangered village

1. Mukul Sharma 1988, Two Villages on Verge of Erosion, in *Navbharat Times,* New Delhi, March 26.

Diara farms

1. Mukul Sharma 1988, Land Relations in the Diara, in *Navbharat Times,* New Delhi, January 22.

Savage harvest

1. Prabha Dutt and Farzand Ahmed 1984, Vicious Vendetta, in *India Today,* New Delhi, January 31.
2. UNI 1984, Piparia may see worse, in *Indian Express,* New Delhi, January 10.
3. Indian Express News Service 1984, Piparia Carnage — Climax of Caste war, in *Indian Express,* New Delhi, January 13.
4. Ved Prakash Vajpeyi 1985, *Bhumi Samasya ki Zamin par hinsa ki phasal, in Dinman,* New Delhi, November 24-30.
5. Farzand Ahmed 1985, The Caste Carnage, in *India Today,* New Delhi, December 15.

Blind Bhagalpur

1. Arun Sinha 1990, Bhagalpur Blindings — 10 Years after, in *The Illustrated Weekly of India,* Bombay, April 1.

Killing fields

1. Rajiv Ranjan Lal 1990, Fear is the Key, in *The Illustrated Weekly of India,* Bombay, February 4.

Coveted islands

1. S M Nurul Alam 1989, Socioeconomic and Political Dynamics of Char Land Settlement and its Implications for Poverty, Paper prepared for the UNDP/UNFPA seminar in Bangladesh in 1989, October 1, *mimeo.*

Fear factor

1. Satish Chandra Singh 1973, *Changes in the Courses of Rivers and their Effect on the Urban Settlements in the Middle Ganga Plain,* National Geographic Society of India, Varanasi.

Rubble rocked

1. Ivo Iliste and Birgitta Goranson, Crisis in the Himalayas, *mimeo.*

The danger zone

1. B G Verghese 1990, *Waters of Hope,* Oxford and IBH Publishing company, New Delhi.
2. Rashtriya Barh Ayog 1980, *Report,* Vol 1, Ministry of Energy and Irrigation, New Delhi.

Future talk

1. Peter Rogers 1989, History of Ganges Water Resources with an eye to the Future, in *Development Ecology,* Vol II, No 1, Patna.

Glossary

Adhwara	River group in Bihar
Ahu	Type of rice
Amrit	Nectar of immortality, Ambrosia
Bichaulias	Middlemen involved in the milk trade in Bihar diaras
Bind	Agricultural caste in Bihar
Bhangar	Transdiara land
Bhumihar	Landowning caste in the Gangetic plains
Bigha	Indian standard for measurement of land (varying approximately from eight bighas to an hectare to three bighas to an hectare)
Bakseesh	Reward for a specific work, Tip
Bhadai	Crop reaped in August
Babul	Acacia Indica
Bil	Wetland (in Assamese)
Burrokh	Type of sugarcane
Benami	A transaction conducted in the name of another person who is not the beneficiary of the deal
Bao	Type of rice
Boro	Type of rice
Bari	Dry terrace (in Nepal)
Ban	Forest
Bhasinu	Slumping of the terrace (in Nepal)
Bazaar	Market place or town
Chakaa	Sand and clay
Chaur	Wetland (in Bihar), Land depression which fills up with water in the monsoon
Char	River island in Bengal
Chapri	River bank made up of silt
Charan	Grazing land
Chipko	Movement to save trees from being felled
Cho	Seasonal stream in Punjab with wide river bed
Dhadi	Caste in Bihar
Diara	Flood plain area of a river (in Bihar)
Daihar	Cattle owner in Bihar who sells milk
Dhanuk	Caste in Bihar
Domat	Type of soil with a lot of clay in it
Dalhan	Pulses
Dhanja	Cracks that appear in terrace farms
Dhar	Substream of the main river (in Bihar)
Dharmijagar	Type of rice
Gwala	Milk seller in the Gangetic plains
Gangatiri	Breed of buffalo
Gangota	Caste in Bihar
Gangol	Caste in Bihar
Ghat	Steps leading to the river, from where a ferry can be operated
Gur	Jaggery, molasses
Gaon	Rural settlement
Gairmajorua am	Common land under government control
Haor	Natural depression
Harijan	Scheduled Castes
Hilsa	Type of fish found in the Ganga
Jotedar	Landowning class in Bengal
Jhaua	Type of grass which grows in Bihar's chaurs
Jalebi	Acacia Arabica
Jhoola	Swing
Jamun	A fruit bearing tree
Jethua khehari	A crop grown in the diara
Jheel	Lake
Jokulhlaup	Bursting of a lake confined by a dam of ice or glacier and moraine
Kisan Sabha	Council of farmers
Katha	Standard of measurement for land
Khasra	Plot of land
Khet	Wet terrace (in Nepal)
Kalai	Form of paddy
Khehari cheena	Form of paddy grown in the diara
Karela	Bitter gourd
Kharif	Crop sown before monsoon
Kaccha	unfinished
Kurmi	Caste in north India
Kankar	Reef

Khadar	Floodplain area of a river in (western Uttar Pradesh)
Karar	Diara land which floods once in a hundred years
Kash	Grass found in the Bihar diara areas
Khairwar	Caste in Bihar
Koeri	Caste in Bihar
Lathiyal	Muscleman, tough
Lathi	Short bamboo pole, which can make an effective weapon in the hands of a trained individual
Maidan	Field
Marwaris	Business caste
Murrah	Breed of Buffalo
Margang	Waterbody (in Bihar)
Mallaha	Fisherfolk in the Gangetic plain
Mand	Deep depression left behind by a river
Mung	Type of pulse
Nullah	Drain
Nadi	River
Nala	Stream
Panidari	Waterlordism
Pains	Artificial channels
Pakho	Untilled terrace (in Nepal)
Padyatra	A march
Padyatri	A marcher
Parwal	Type of vegetable
Panchayat	Council of village elders, now an elected body
Rangdari	Money extorted by gangsters in Bihar
Raj	Rule, usually in reference to British rule in India
Rajput	Landowning warrior caste of north India
Rabi	Crop sown in winter
Raja	Local chief, ruler
Shramdan	Voluntary labour
Shahabadi	Cattle breed
Sheesham	Indian teak
Sahni	Fisherfolk in Bihar, near Kharbatal
Sali	Type of paddy
Sal	Shorea robusta
Santhal	Tribe
Tanti	Caste in Bihar
Telhan	Oilseeds
Tal	Waterbody, lake
Vedic	Referring to the Vedic age, the time period relating to the coming of the Aryans in India
Yadava	Agricultural caste in the Gangetic plain
Zaid	Winter crop
Zamindar	Landlord
Zamindari	Landlordism

CSE
Publications

THE STATE OF INDIA'S ENVIRONMENT 1982
THE FIRST CITIZENS' REPORT
Paperback 200 pages

THE STATE OF INDIA'S ENVIRONMENT 1984-85
THE SECOND CITIZENS' REPORT
Paperback 398 pages

TEMPLES OR TOMBS?
DECISIONS IN THREE ENVIRONMENT CONTROVERSIES
Paperback 285 pages

THE WRATH OF NATURE
IMPACT OF ENVIRONMENTAL DESTRUCTION ON
FLOODS AND DROUGHTS
Paperback 70 pages English/Hindi

FIGHT FOR SURVIVAL
PEOPLE'S ACTION FOR ENVIRONMENT
Paperback 160 pages

TOWARDS GREEN VILLAGES
A STRATEGY FOR ENVIRONMENTALLY SOUND AND
PARTICIPATORY RURAL DEVELOPMENT
Paperback 52 pages

GLOBAL WARMING IN AN UNEQUAL WORLD:
A CASE OF ENVIRONMENTAL COLONIALISM
Paperback 36 pages

GREEN FILM GUIDE
A CATALOGUE OF VIDEO FILMS ON THE ENVIRONMENT
Paperback 44 pages

The Centre for Science and Environment (CSE) is a non-profit, public interest research organisation which aims to create an informed public opinion about the need for rational, equitable and sustainable management of natural resources keeping in view the needs of the poor.

CENTRE FOR SCIENCE AND ENVIRONMENT
F-6 Kailash Colony, New Delhi 110048